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A FURTHER STUDY OF THE DELAYED REACTION IN THE ALBINO RAT

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I. INTRODUCTION

Natural history is replete with descriptions of situations in which animals, in their natural habitat, apparently are reacting to a determining stimulus which is not present at the moment in which the response is made. A typical example of such behavior, provided we ignore possible olfactory stimulation, is provided by the grey squirrel in the following type of behavior: The animal may frequently be observed burying nuts and other bits of food in the ground in the environs of its home tree. At some later time the animal may, furthermore, be observed returning and, without any apparent hesitation, going to the spot where the food was buried and recovering it. It has generally been supposed that it was guided during this behavior by the olfactory sense but the observations of Frost (5), Klugh (14), Dice (4) and others indicate that it may be necessary to find some other mechanism whereby to account for this behavior for these observers report observations, which, while they do not entirely eliminate the possibility of olfactory stimulation, yet, make such a possibility appear rather remote.[1] Nor is this type of behavior

[1] Frost observed a grey squirrel detecting and recovering buried nuts and assembling these nuts at a single protected spot after a snow fall of about 2 inches.

limited to the squirrel. It may, if we again neglect possible olfactory stimulation, be seen in the carnivorous animal stalking its prey in the dense undergrowth of the forest. Domesticated animals also exhibit the same type of behavior under various conditions.

Instances of behavior such as the foregoing have been noted by psychologists and others and various explanations have been proposed. These range all the way from explanations attributing ideas and mental images of the various objects which served as stimuli, to explanations which deny to the animal under such conditions all behavior except such as is directly due to direct stimulation and its immediately accompanying response.

In order to make an analysis of the type of mammalian behavior which has been mentioned above, under the more controllable conditions of a laboratory experiment the delayed reaction experiment was instituted. Here associations are set up between some stimulus, for example, a light, a sound, certain movements of the experimenter, etc., and certain movements on the part of the animal which produce some form of reward for the animal. Having established this association, a period of delay is introduced between the moment when the stimulus is presented and the moment when the animal can make the particular series of movements leading to food or some other form of reward. If the animal can still react correctly after a period of delay in which

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Eight nuts were recovered while the observer watched. Only one time did the animal dig without apparent results. In five of the eight times the squirrel first mounted a post and apparently surveyed the untracked snow then went directly to the place where the nut was buried. Klugh reports observations on a squirrel which had buried nine nuts in the snow on his balcony. During the night there was another snow fall and the new snow covered the former snow by an additional foot. The next morning the squirrel returned and without hesitation dug up the nine nuts. Dice, in turn, reports an experiment which he performed with a fox squirrel which was in the habit of coming to a porch of his home and securing black walnuts kept there in a box. Finally, the nuts were removed and the box filled with dry sand. Some black walnuts were completely buried in the sand, others were partially buried while others were exposed to view. Even though the squirrel returned frequently to the box it never found any of the nuts save those which were exposed to view. It frequently dug in the sand in the box but found none of the hidden nuts. If only the tip of a nut was exposed it was found sooner or later but never when the entire nut was completely covered.

the determining stimulus is absent, it must have some mechanism that functions for the stimulus in initiating and guiding the correct response.

In any study of the delayed response two principal questions arise. The first of these questions deals with the period of time over which the animal can delay after the determining stimulus has been withdrawn and still make the correct response. The second question is concerned with the mechanism by means of which the animal is able to bridge the delay and yet react correctly after the period of delay. This latter question must be answered on the basis of behavior cues which the animal may demonstrate during the time that it is in the problem situation or on the basis of controls which the experimenter may introduce into that situation, or perchance by a combination of these two conditions.

Numerous experiments have been performed on animals selected from the different species of the animal kingdom from the chicken to the human child of eight. On the basis of those studies in which the animal was capable of making the correct response after the delay, it appears that the delay period is bridged either (1) by maintaining overt bodily attitudes and then after the delay reacting on the basis of those overt bodily attitudes, or (2) by means of some intra-organic cue which may be maintained during the delay or be reinstated after the period of delay. Several studies (6), (21), have indicated that rats, dogs and cats were able to react correctly after delay provided the first of the above methods was used in bridging the delay whereas raccoons, apes, and children could react correctly when these overt bodily attitudes were not maintained and consequently must have been reacting on the basis of some intra-organic cue. Some more recent experiments on dogs (19) and cats (1), (3) indicate, though not conclusively, that these animals too, can delay without maintaining bodily orientation.

Since Hunter's experiment no one had utilized the albino rat as subject in the delayed reaction experiment and yet this is probably the most favorable animal to use in studying this problem provided it can be demonstrated to possess the ability to react

on the basis of non-overt bodily attitudes. While Hunter's experiment shows conclusively that in the particular situation used in his experiment the animal maintained gross bodily orientation yet by using a different situation it might be possible to discover that, when circumstances demanded, the rat too could react without bodily orientation.[2] This belief is given additional credibility when we consider the squirrel mentioned in the early part of this section. Here is an animal which is apparently reacting to an absent stimulus, if we neglect the not entirely eliminated olfactory sense, after a long period of time without orientation in the meanwhile and yet which belongs to the same general class of animals as does the rat, namely, the rodents. If then the squirrel is able to react on the basis of some intra-organic cue we should expect that the rat, which has approximately the same type of nervous system as does the squirrel, should likewise be able to react on the basis of intra-organic cues provided the situation can be found to bring out such behavior. Reaction by gross bodily orientation is probably easier for the animal than the building up of intra-organic cues but what will the animal do when it gets into a situation in which it cannot react on the basis of gross bodily orientation?

Furthermore, the only type of stimulus that had been employed in experiments on delayed response in the rat were visual stimuli. Yet it is a well established fact that these animals make little use of vision in most situations. It might then, be possible that the ability of the animal to delay has been tested by means of one of its least used sense avenues. It is quite possible that were some other sense used, for example, one which the animal ordinarily uses in its more natural environment, that not only would the period over which it could delay be lengthened but it might be found capable of responding correctly after delay without having maintained gross bodily orientation.

In view of the foregoing considerations, it was decided to make

[2] Since the formulation of and experimental work on this problem was undertaken, there have appeared in the literature two studies on rats (26, 27) in which by the use of different situations evidence was found that the animals reacted without maintaining bodily orientation.

an attempt at a further analysis of the behavior of the albino rat in a situation involving a delayed response. The only type of situation involving the delayed response, in which this animal had been tested was that used by Hunter (6). In that situation a stimulus is presented to the animal and then after a period of confinement in a relatively small space, the animal is released in order to react to the stimulus which has been removed in the meanwhile. It is also possible to arrange a situation which will require response to an absent stimulus but instead of keeping the animal confined during that period of delay, will keep the animal in motion between the giving of the stimulus and the time when the final reaction to that stimulus is required. A situation such as this is probably more nearly the type of situation which the animal would meet in its natural habitat than is that mentioned as the first method above. Accordingly this is the situation which was used in the experiments reported in this study.

In addition to the study of the delayed response in a situation different from that previously used with the albino rat, we attempted to study the effect on the delayed reaction of stimulation through various senses. These problems were studied with reference to their bearing on the aforementioned questions which arise in any study of the delayed response, namely, (1) the period of time over which the animal can delay after the determining stimulus has been withdrawn and still make the correct response; and (2) the mechanism whereby the animal makes the correct response.

II. CRITICAL REVIEW OF PREVIOUS WORK

The first attempt to study the delayed response under the controlled conditions of a laboratory situation was made at the suggestion of, and under the direction of Harvey A. Carr at the University of Chicago. The earliest actual work on this problem, suggested by Professor Carr, was done by a graduate student, W. R. Hough, whose work was followed by work on the same problem by H. S. Reed. Neither of these two students carried the work to completion and as a result their work served rather as preliminary to the later work of Walter S. Hunter

which was done during the years of 1910 to 1912. Since Professor Hunter's experiments with rats, dogs, raccoons and children, a number of researches have been made on the delayed response utilizing various species of animals, i.e., cats, dogs, monkeys, apes, and children, as subjects.

A. Methods and apparatus used in studying the delayed reaction

Hunter (7) has pointed out the essential features which any apparatus and method must embody in order to study the delayed response. These as noted by him are:

1. It must be adapted to the size of an animal or subject and its mode of response.
2. It must provide a means for presenting a stimulus in one of several places.
3. These stimulus places must be equally accessible to the response.
4. The stimulus and method should be such as to present no differential cues to the subject during the intervals of delay.

These features have been embodied in the experiments which have been done on this problem or at least an attempt has been made on the part of the experimenter to do so in devising his apparatus and method and I believe that in the main they have succeeded except it might be that in some cases the fourth of these features has not been sufficiently guarded and if so the experiment was no delayed reaction experiment. In general the methods which have been used may be divided into two general classes, namely:

1. The "indirect method," which was the first to be used, and
2. The "direct method."

In the following pages of this section we shall attempt to describe first these two general methods of studying the delayed response and some of the variations employed by the different experimenters using the method and second, the results obtained by these experimenters under the various conditions which they set in their experiments.

The principle involved in the studies using the indirect method is that of establishing, by trial and error learning, an association

between a stimulus, i.e., a light in a certain position, or a sound, and a series of movements on the part of the animal, which lead to food. As soon as the animal has learned the relationship between the stimulus serving as the cue and the food the actual experiment involving the delayed reaction is instituted. Instead of having the animal make the necessary series of movements while the stimulus calling them forth is still present, the stimulus is given and then, only after a period of time, is the animal permitted to make the final reaction necessary to obtain the food. This was the method first used by Hunter (6) in his famous experiments and later by Ulrich (18), Yarborough (21), Walton (19) and Honzik (27).

In order to secure a situation adapted to the above method, Hunter (6) used a box composed of five chief compartments namely, a release box, a larger compartment into which the animal was released from the release box, and three smaller compartments each containing a light which, when lighted, served as the stimulus. Small doors directly in front of the lights connected these light boxes with the larger compartment. The light boxes, on the other hand, were so arranged that the animal after entering them left by means of a second opening and was directed back to the entrance of the release box where, when the proper choice had been made, it obtained food. (This was the arrangement used by Hunter with his raccoons, dogs and some of the rats. With the rest of the rats, food was given at the exit doors of the lighted boxes. Hunter does not state explicitly which animals composed the latter or former groups of rats unless it is implied that the ones trained without punishment were fed at the exit doors of the light boxes. He does state that the one of the two boxes used with rats was not wired for punishment and that in this box the animals were fed at the exit doors. This may imply that the group trained without punishment were all trained on this box but it does not necessarily do so. If they were, then the animal with the longest delay was trained with food given at the exit door of the lighted box.) Ulrich (18) in his study on the integration of movements in learning in the rat studied the delayed response in connection with "posturing" and used the same

type of apparatus except that it was larger than Hunter's and instead of rewarding the animal in the vicinity of the release box the animal was rewarded with food in a second compartment attached to the light or stimulus box. Furthermore, instead of supplying his stimuli by means of 8 c. p. bulbs as Hunter had, he used 50 Watt bulbs. Both of these features, the offering of reward in the compartment attached to the stimulus box and this larger light, would increase the difficulty of controlling these features. It is conceivable that in this apparatus immediate stimulation may have been present. Yarborough's (21) apparatus was a duplication of Hunter's apparatus except that it was adapted to the increased size of his animals (cats). His method also was identical with that of Hunter's. In addition to using light as the cue, he also used sound supplied by means of small buzzers suspended in the stimulus boxes by means of coiled wire, attached to the ceiling.

Walton (19) used an apparatus which while identical in principle with that of Hunter's differed somewhat in arrangement. The animal was confined during the period of delay in a release box adapted to the size of the animal, a dog in this case. Directly opposite and about 12 feet from the release box were three stalls holding the stimulus lights. These three stalls were on the same ground level. In some of the tests, a fourth stall was added which was not on the same ground level as the others but was located above the others and was reached by means of a plank placed at a 30 degree incline. Reward was given in the correct stall whenever the animal made the correct choice. Varying conditions were investigated in the experiment. These were for the purpose of studying the difference in reaction when the release box faced the stalls containing the stimulus; when the release box faced the food compartments during the giving of the stimulus but during the delay period was turned at an angle of 90 degrees; and when diverting stimuli were applied during the delay both when the release box faced the stalls, and when it was turned at the 90 degree angle. The diverting stimuli consisted of (1) the sight of the experimenter walking around in front of the release box during the period of delay; (2) the experimenter

calling the dog; and (3) the operator whistling to the dog and hanging a piece of meat at the front of the release box.

Honzik's (27) apparatus for studying delayed reaction in the rat also utilized the general principle of Hunter's set-up but differed from it in that the animal, by running up to the stimulus, made a more definite reaction to it. Advantages of this arrangement were that the experimenter could determine that the animal had received the stimulus and that it might serve to reinforce the stimulus. The apparatus consisted of a release box; a large discrimination chamber at one end of which were three doorways covered by stimulus curtains, two black and one white; and an elevated path leading to food boxes. Directly in front of the stimulus curtains was a large screen which was lowered during the delay period. In the delayed reaction tests the animal, released into the discrimination chamber, ran toward the white curtain. Just before it reached the curtain, the screen was lowered and the animal was confined in the discrimination chamber for the period of delay, at the end of which the screen was raised and the animal was confronted with three black instead of one white and two black curtains. Its problem was to pass through the door which originally contained the white curtain. Punishment could be administered when the animal attempted to pass through the wrong door.

The principle involved and the apparatus used in the direct method differ somewhat from those employed in the indirect method. The principle employed in this method is that of utilizing an association, between some stimulus and reward, which has been previously formed, or, at least, one which is so intimately connected with the animal's past experience or native constitution that little or no training is required to set it up. After the presence of the association has been determined, a period of delay is introduced between the giving of the stimulus and the final reaction. In the use of this method various forms of apparatus have been employed.

The direct method was first used in investigating the delayed response by Hunter (7) in the study in which his daughter, Thayer, was used as subject. In this experiment the small child

was seated in front of three small boxes. The experimenter permitted the child to see him hide a toy or other stimulus object in one of the three boxes. During the following period of delay the child was disoriented and then at its conclusion was permitted to take the toy or other stimulus object from the box, provided a correct choice of box had been made. Hunter points out in the study that here an association was used which did not have to be learned at the time of the experiment. Yerkes (23) in studying the gorilla, Congo, studied delayed response by the same method, except that instead of only three boxes, five were used. This was the multiple choice apparatus designed by Bingham. Directly outside of the grill forming the front of the gorilla's cage was placed the board holding the five choice boxes, the board being so arranged that the ends slid in ways on the platform. This enabled the experimenter to pull the board out of the reach of the gorilla when the stimulus was to be placed into the box as well as during the delay period. At the end of the period of delay the board was pushed to within the reach of the animal. During the delayed reaction experiment, the animal was permitted to see the experimenter bait the proper box. The period of delay then intervened and, at its conclusion the board containing the boxes was pushed within the reach of the animal which was permitted to select one of the boxes. If the choice was correct the animal obtained food from the box, if incorrect it found the box locked. Tinklepaugh (17) in his study on representative factors in monkeys used a method and apparatus similar to that of the two preceding investigators. It differed, however, in that the animal was placed on a chair about eight feet distant from the food containers of which there were only two. The animal was again permitted to see the experimenter bait the food container. A board used as a screen was then placed between the animal and the food containers during the delay period. At the end of the delay the animal was given the signal to leave the chair to go and get the food. Various other situations were used in which the animal was disorientated and distracted during the period of delay.

A somewhat different arrangement of apparatus is found in

the experiments of Yerkes (23) on the further study of delayed reaction in the gorilla, of Yerkes and Yerkes (25) on their study of Chimpanzees and of Adams (1) in his study on cats. In these three studies the following procedure and arrangement of apparatus was employed. The animal was confined in the center of the experimental situation. In the two former studies, the gorilla and the chimpanzees were tied to a mooring post whereas in the latter study the animal was confined under a wire basket in the center of the room. In four different directions from this place of confinement were placed small boxes which were identical except for certain factors such as color, etc. The procedure consisted of allowing the animal to see the food being placed in the box. Then during the period of delay the behavior of the animal was either observed by the observer from another room, if the animal remained in the situation, or the animal during the longer delays was removed from the room entirely and either set to other tasks or taken back to its sleeping compartment. After the period of delay the animal, if it had been removed, was returned to the mooring post or cage (in the case of the cats) and after a brief interval released. If the animal went to the proper food box and opened it, food was obtained, otherwise no reward was obtained.

Yerkes (24) in his further study of the gorilla, Congo, due to the limitation of space which prevented using the above method and further intending to avoid the factor of location in which the food container was baited, devised and used the following apparatus and method. A turn-table 60 inches in diameter was mounted on a platform directly in front of the grill of the gorilla's cage and 24 inches from it. On this turn-table were placed six tin kitchen canisters. The canisters differed in size whereas the sets were distinguished by means of different colors. This made it possible to vary either size or color. The procedure consisted of baiting the can directly in front of the grill and covering it. The table was then rotated until the food container was in some other position than that in which the animal had seen it baited. After an interval of delay the gorilla was permitted to reach through the grill and turn the table so the proper canister

came into position directly in front of and at the nearest point to the grill. When it had been turned into that position, the experimenter gave the animal the food provided the proper canister had been selected, otherwise the animal received no food.

Maier (26) attempted the use of the direct method in studying the delayed reaction in the rat. His set-up consisted of three ring stands placed on the floor of a room which had previously been thoroughly explored by his animals. From the floor the animal could climb to the top of a ring stand by means of a wire ladder and thence, if the correct ring stand had been chosen, could pass to the food table via an elevated path. His method consisted in placing the rat at the bottom of the selected ring stand and then allowing it to climb to the top and cross the elevated path to food. Two similar trials followed immediately and then a period of delay was introduced. After the delay period the rat was placed on the food table but in such a position that it was unable to get food except by descending a ring stand adjacent to the table, crossing the intervening floor space to the ring stand used in the three preceding stimulus runs and then proceeding as in those runs.

A somewhat different type of situation and yet one which involved the direct method was that employed in the food burying experiments of Kohler (12), Yerkes (23), Yerkes and Yerkes (25), and Revesz (16). In all of these experiments the animal, from its place of confinement, was permitted to see the food buried in a homogeneous plot of ground. After the food had been buried the animal was removed. Immediately after the removal of the animal, if the delay was to be one of considerable length, precautions were taken to prevent odor of the food from permeating the ground. After the period of delay the animal was returned and released in order to see if it could still find the location of the food and recover it.

A more complicated situation involving the direct method was the one used by Kohts as reported by Yerkes and Petrunkevitch (13). This might be designated as the method of "choice by sample." She first taught her young chimpanzee, Iona, to match

colors, etc. She then handed the animal some material, of a certain color, for example, and the animal was required to pick from an array of other colors on the table the one corresponding to the color which he held in his hand. Having learned to do this the animal was given material of a certain color which after a few seconds was again taken away. A period of delay then intervened before the animal was permitted to select the material corresponding to the sample.

Buytendijk (2) in attempting to test out the delayed reaction by a more natural method than that employed in the researches of Hunter reports that he accomplished this by throwing a piece of food to the animal and then while the animal was watching threw out three additional pieces. The animal ate the first and then after various periods consumed in eating, etc. went directly to the others in turn and ate them.

Other studies which involved the direct method to a greater or lesser extent were those of Cowan (3) and of Nellmann and Trendelenburg (15). Cowan utilized an ordinary living room with doors at opposite sides of the room connecting with a kitchen. The subject, a cat, was confined either on the sofa or in the center of the room. The experimenter appeared at one of the other of the doors holding in her hand a dish containing a piece of food. As soon as the cat had apparently seen her, she retired to the kitchen and placed the food on the floor under the stove. The animal was then released and observed, when she reached the kitchen, by the experimenter through a small window from the porch. If the cat had come through the same door at which the experimenter had last appeared she obtained the food, otherwise the food was taken away from her.

Nellmann and Trendelenburg (15) employed a small problem box, the door of which was hinged at one side and opened at the other side. The animal, a monkey, was shown the food being placed in the box. On being released he was required to go to the box and open it in order to obtain the food. The problem was now complicated by turning the box at various angles so that the animal had to approach the box from various directions to open it. Having learned to go always to the side of the box on which it

opened, periods of delay were instituted. The animal now had to remember during the period of delay whether the box had been turned or not from its original position and if so in which direction.

It must be understood, of course, that when we divide the foregoing methods of investigating the delayed response into "indirect" and "direct" methods we make such a division on a relative and not on an absolute basis. These two methods are not mutually exclusive but are only relatively different. Both involve the use of associations which must be established at sometime or other during the animal's experience. In this respect the methods are the same but they are relatively different in that the indirect method makes use of an association which must be built up "de novo" or at least nearly from that point whereas in the direct method an association is selected which, at least, is partly learned before the experimenter undertakes training the animal. In the course of a relatively few trials the experimenter perfects the particular association to a point where it can be used satisfactorily in the investigation.

Then too, the two methods differ in the particular type of association used, that is, in the indirect method the association which is set up is usually one such as between a light, a sound or some similar stimulus and food. This is a type of association which the animal has not experienced in the past. In the case of the direct method, the association is usually between seeing certain movements on the part of the experimenter and food or perchance between the seeing of food and certain movements on the part of the animal. As far as the present writer is aware the exact association or associations involved have never been determined. In the situations employed there is always a possibility of several associations that might be involved.

One of the criticisms which has been put forward against the indirect method is that first pointed out, I believe, by Buytendijk (2), namely, that an attempt is made to use an association which has no biological significance for the animal. Köhler (11) has made about the same criticism when he states that in using a discrimination method of investigating memory we are presenting the animal (apes) with a situation which presents no sensible

relationship to the animal, i.e., it cannot give evidence of insight into the problem but must learn the problem by trial and error just as the rat or any other of the mammals. Now the question arises as to why the primates cannot see a sensible relationship in this particular problem. Is it due to the fact that lights have no biological significance for the animal or is it rather that here we reduce the ape to exactly the same position as the rat and compel it to form an association from its very beginning rather than by taking a situation which has previously been experienced, at least in part, and has already acquired a certain "meaning" for the animal? This may merely be evidence pointing to what may be a fact, namely, that the actual learning ability of the ape is not so much higher than that of the rat when they are learning equally new situations.

It appears to the writer that the difference between the two methods are differences similar to those found between non-sense and meaningful material as employed in the investigation of memory in the human being. Here, too, we find differences in the rate at which the necessary associations are set up and possibly in the period of time over which the material can be recalled or reinstated. Both have been used in the investigation of memory but when we want to study the memory process under the most completely controlled conditions non-sense material is used rather than meaningful material.

Some experimenters attempting to use a direct method have utilized what have been called food burying experiments. With this method delays of much greater duration have been found for primates than with any other methods. Yerkes (23, p. 98) points out that this is a "crude test or method of sounding for memory" since it does not exhibit anything peculiar to apes but that there is evidence that other animals exhibit it in a very proficient manner.

B. Experimental results obtained in previous studies

As was previously pointed out, two main problems arise in the study of the delayed response experiment. These are: (1) How long can the animal delay after the stimulus has been re-

moved and still react correctly, and (2), what is the mechanism by which the animal reacts after the delay to a stimulus which now is absent? Of these two problems, of course, the second is considerably the more important.

1. Length of delay obtained with different species of animals. The albino rat is probably the lowest species in the biological scale which has been found capable of reacting in the delayed reaction problem. Revesz (16) attempted the direct method using chickens as subjects but was unable to secure a delay long enough even to bury the grains and then have the chicken peck or scratch for them. The animal refused to react to the grains as soon as they were out of sight.

Two experimenters have previously worked with the albino rat, Hunter (6) and Ulrich (18). Both of these experimenters found that the animal was able to react to the absent stimuli, but the period of delay found by Hunter did not exceed 10 seconds when three boxes were used, and that length was found in only one case. He used fourteen rats. Four of these were able to react after a period longer than one second, the others were one second or less. When, however, he employed only two of the three stimulus boxes he found that the period of delay for three of the five rats so tested increased from one to five seconds. Hunter's results were computed on the basis of 25 trials giving ten trials per day. Ulrich tested eleven rats and found periods of delay up to 50 seconds in the case of one animal, but in this as in the case of a number of animals, the percentage of correct choices was only slightly above what one would expect on the basis of pure chance with an infinite number of trials. Furthermore, some question might be raised as to controls used in the experiment.

Two more recent experimenters Maier (26) and Honzik (27) have also worked with the albino rat. The former utilizing a direct method reports delays up to 24 hours, while the latter experimenter reports delays ranging from 7 seconds to 45 seconds with some evidence of delays up to 3 minutes.

Yarborough (21), Cowan (3) and Adams (1) have used the cat in studying the delayed reaction. Yarborough as indicated

above used the indirect method, Cowan a modified direct method and Adams used the direct method as previously used by Yerkes in his study of the gorilla. Yarborough found that when three choice boxes were used the cat could delay for periods of from 2 to 4 seconds. With two choice boxes, however, the period of delay could be increased from 2 to 4 seconds, to from 16 to 18 seconds. Cowan, using her own method, found delays, with the single animal used in the experiment, of about 30 seconds. Here two choices were possible. Adams, using the direct method, offering four possibilities of choice got delays of 16 hours with one animal.

Two researches Hunter (6) and Walton (19) report the use of dogs as subjects both of which used what we have designated above as indirect methods. Hunter reports that his dogs were able to delay and yet make a high percentage of correct responses one after 5 minutes and the other after only a 2 second period of delay. Walton on the other hand, reports delays of 1 minute with the four compartments and longer delays with fewer compartments.

Only one study appears in the literature which utilized raccoons as the experimental animal. This was the early study of Hunter (6). Using the indirect method employed in the study, he found that the raccoons could react correctly after delay when 3 boxes were used for from 3 to 15 seconds. When only 2 choices were possible the period of delay would be increased up to 20 and 25 seconds and still have a high percentage of correct responses.

Buytendijk (2) using a direct method in which he threw pieces of food to the monkey and then after the animal had grasped the first piece, threw several more pieces in other directions while the animal watched. The animal then ate the piece which he had grasped first and then in turn the other pieces. The whole procedure involved about 7 minutes before the last piece was eaten. This would indicate that the animal was able to remember the location of the food for that period of time at least. Nellmann and Trendelenburg (15) using the method involving the hinged box found that if a delay of from one-fourth to one-half minute was allowed to intervene between the turning of the box and the

release of the animal, it was no longer able to remember which side to approach to open the box. Tinklepaugh (17) on the other hand, using the direct method found delays of from a few seconds to from 15 to 20 hours.

As in the case of monkeys so in the case of chimpanzees, several different methods have been applied in the study of the delayed response. All of these methods however, would appear to fall into our classification of the direct method. Kohts (13), with her chimpanzee, Iona, used the method of "choice from sample" and found that if more than 15 seconds was allowed to elapse between the removal of the sample and the selection of the correct object to match the sample the animal was unable to make the correct choice. Yerkes and Yerkes (25) using the method described under "Methods" above found that their chimpanzees could delay up to 3 or 4 hours with 4 choice boxes present. When, however, the experiment was varied so that the absolute and relative position of the boxes was eliminated the animals made no delays longer than 30 minutes but the authors state that they had not yet reached the limit of the animals ability. In the same study the authors report experiments in which the food was buried in a large pasture. The animals apparently were able to react correctly to the buried food situation after a period of 48 hours. Kohler (10) in his early experiments on the chimpanzee reported delays in buried food experiments after intervals of $16\frac{1}{2}$ hours.

Yerkes (23) in studying the gorilla made some experiments on delayed reaction also using the technique and situations described above under "Method" found that the animal could delay in the situation involving the four choice boxes after a delay of 3 hours. In buried food experiments the animal reacted correctly after 48 hours.

Apparently only two studies have been done on young children. Both of these studies were done by Hunter (6) (7), one using a modification of his apparatus involving the indirect method and the other using a direct method. With the indirect method, he obtained correct responses from the children after delays of 25 minutes. In the study involving the direct method (7) Hunter

tested a child younger than any of the children tested in the previous experiment. Here he found that the child could delay for from 20 to 24 seconds and still make a fairly high percentage of correct choices.

From the foregoing summary of the length of delays that the various animals were able to bridge and still make the correct response, it is apparent, if we assume that all experimenters exercised the proper controls in their experiments, that the period of delay which the animal can make is dependent upon a considerable number of factors. It appears that the length of delay is a resultant of among other factors, (1) the type of apparatus used; (2) the method employed; (3) the species of animal used; (4) the kind of association utilized; and so on. We shall consider these later.

2. Factors producing correct post-delay responses. As was indicated above, the most important problem from the standpoint of psychology, which arises in the delayed response experiment is not how long can the animal delay after the removal of the stimulus and still make the correct response, but rather, upon what basis is it possible for the animal to react to a stimulus which was present for a time and then is removed. From analysis of the problem Hunter (6) concludes that there are at least two possibilities: (1) the animal may maintain gross bodily orientation or orientation of some part of its body during the delay and then when released react on the basis of that orientation. Or perchance, the animal may by chance recover the proper orientation just at the moment of release and thus still react on the basis of that orientation; or (2) the animal might react, providing it does not maintain orientation, on the basis of some intra-organic factor which is non-observable by the experimenter. If the animal can be shown not to react on the basis of orientation, then this intra-organic cue must be present. If it is, it might again, according to Hunter, be either sensory or imaginal. In either case it would perform the function of serving as a representation of the stimulus, i.e., it would be ideational in its functioning.

Accepting Hunter's analysis of the problem the necessity then

arises to determine whether or not an animal solves the delayed response situation by maintaining gross bodily orientation or the orientation of some part of the body, and if it does not, to determine the intra-organic cue which the animal used as a basis for its reaction. Furthermore, it must be determined, if possible, what the nature of this cue is, that is, whether it is sensory or imaginal. Another problem which would naturally arise from the above would be whether or not the sensory or imaginal element remains in the highest level of nervous activity, namely, in attention during the delay or if it does not under what conditions it can be reinstated. We shall now consider what evidence has been gathered from the behavior of the animals in previous experiments which throws light on these problems.

The experimental evidence produced by Hunter (9) and Ulrich (18) would indicate rather clearly that at least in the type of situation which they used, if the rat can delay at all, it does so on the basis of the maintenance of gross bodily orientation. If the bodily orientation of the animal was disrupted during the period of delay the animal could not make more correct responses in a series of trials than could be accounted for on the basis of chance. Furthermore, the evidence from Yarborough's (21) experiment on cats would indicate likewise that when the cat is placed in a situation and handled by a method similar to that used by Hunter the animal when it reacts correctly does so by the maintainance of overt bodily attitudes. Hunter's (6) experiment again would indicate that the dog in order to react successfully after a period of delay, must do so by means of the maintainance of the orientation of some part of the body.

On the other hand, evidence that animals make use of intra-organic cues in their reactions in the delayed response situation are not lacking. Hunter (6) found that in the case of his raccoons and children correct reaction could be made without the maintainance of overt bodily attitudes. In this case, not only was the orientation not maintained in the release box, but even after release, the animal might change its orientation and still make the correct response in more cases than could be accounted for on the basis of chance reactions. Furthermore, the behavior

of the animal was such as to indicate that it was not making a chance reaction. Other experimenters, such as Cowan (3) and Adams (1) using different situations and methods have presented evidence that with cats also the correct reaction can take place after delay without the maintainance of overt bodily attitudes. Providing their experiments were properly controlled their evidence would indicate such to be the case. Walton (19) working with dogs in an apparatus somewhat similar to that of Hunter's found that when he rotated the release box the animal was able to react correctly. He concludes that the dog does not react on the basis of orientation but as Hunter (7) has pointed out the evidence which he presents does not entirely exclude such a possibility. It merely shows that the orientation could be disturbed during the delay period. It may, however, have been reinstated before the animal was released from the box. Hunter seems to think that if such were the case it would be a separate problem that should be investigated. To the present author such does not seem to be the case. The mechanism which must be functioning in this case could quite easily be the same mechanism that is functioning when the animal reorients after it has once left the cage. All experimenters who have worked on this problem utilizing monkeys (Buytendijk (2), Nellmann and Trendelenburg (15), and Tinklepaugh (17)), chimpanzees (Kohler (10), Yerkes and Yerkes (25), and Kohts (13)), the gorilla, Yerkes (23), and Children (Hunter (6) (7)) cite results which indicate that these animals in various situations can react on the basis of some non-observable intra-organic cue.

If then, the foregoing species of animals can react on the basis of an intra-organic cue, the question remains concerning the nature of this cue. Is it sensory or is it imaginal? Watson (20) in discussing Hunter's results from his earlier experiment agrees with Hunter's main analysis of the possibilities of solution, but differs with Hunter on the basis for explanation of the raccoon's behavior. According to Hunter (6) they reacted on the basis of what he called sensory thought, which was largely a reinstatement of kinaesthetic processes. According to Watson there is "no known mechanism" whereby the behavior could be

explained except on the basis of the use of language habits provided a delayed response situation was actually present. Since such habits were out of the question Watson seems inclined to believe that the animals may have been reacting on the basis of sensory stimulation. This was written before Hunter had performed his experiment on his own daughter and shown that even though language habits had not yet developed the child could still react after delay. In a review Hunter (9) has pointed out the possibility of a reinstatement of kinaesthetic processes which might function as a representation of the stimulus, and on this basis again concludes after the study of his daughter, Thayer, before language habits had developed, that the intra-organic cue may be present even though language habits have not yet developed and furthermore, that these cues are in all probability a reinstatement of kinaesthetic processes.

Another factor producing correct post-delay response and which should be mentioned here is the position factor. Yerkes and Yerkes (25) in their study of the chimpanzee, Yerkes (23) on the gorilla, and also to some extent Tinklepaugh (17) in his study of the monkey found the correct delay after reaction was facilitated when the postion factor was not eliminated from the situation, i.e., when the food container was placed in the same position after the period of delay that it had been in during the period when the animal saw the experimenter place the food in the container the animal reacted correctly to the situation with greater facility than when the position of the container was changed during the interval of delay. In the case of the study mentioned above made by Yerkes and Yerkes, they found that when this position factor was removed and when the animal had to react on the basis of some other differential factor in the situation the animal became at first, entirely incapable of correct response. After a period of training, however, the animal acquired some ability to react on the basis of a differential quality other than position, in this case the color of the box. These experimenters conclude that such response involves, in all probability representational processes, "probably they are symbolic; possibly, imaginal" (p. 269). Tinklepaugh, again in the study

mentioned above found that in the case of one of the animals investigated it was apparently reacting on a basis of position in relation to itself whereas the other animal was reacting rather on the basis of the position of the container in relation to the rest of the environment.

In Tinklepaugh's study an attempt was made to study further the nature of the representative factors used by his animals. In order to throw further light on the subject he employed the "substitution method" which had been used in studying memory formerly by Buytendijk in his study of the monkey. By this method the animal is permitted to see the experimenter place food under or in the food container. During the absence of the animal or during the period of delay, the experimenter replaces the kind of food which the animal saw placed under the food container by some other kind of food or he places the food in some other container. The animal then returns and the behavior is observed. When Buytendijk used this method he observed that the animal on returning to get the food expressed "*etonnement*" when it was not found in the original postion and then went to the other container and secured it. In Tinklepaugh's experiment the substitution of food was used with this method. The foods substituted were bananas and lettuce. If the experimenter permitted the animal to see banana placed under the food container and then during the period of delay, substituted lettuce for the banana, the animal after delay approached the container lifted it and failing to find the banana expressed, as Tinklepaugh states it, "disappointment." If later lettuce was placed in the container while the animal was watching the process and the animal was removed from the situation for a period of delay and then returned it went to the container and ate the lettuce. But if now, at a later time, the substitution was tried again, but this time the animal saw the experimenter place lettuce in the container and during the period of delay banana was substituted for it, the animal returned and without hesitation, at least as far as Tinklepaugh points out, or "etonnement" picked up the banana and ate it. In the present writer's estimation experiments of this kind are of little value in studying the nature of whatever

intra-organic cues are present, for the difficulty of properly controlling the situation is extreme. Before such evidence can carry much weight the experimenter must determine definitely the preferences of the animal and at the same time must produce evidence that the animal has not become habituated to obtaining a certain type of food in the experiment. To a certain extent similar behavior can be shown in the rat. If it is accustomed to receiving one kind of food in the problem situation and is then given another it is likely to hesitate and in some cases would refuse entirely the new kind of food.

From the foregoing summary of the experimental work which has been done by previous workers on the delayed reaction problem, it may be seen that many variations of both the direct and the indirect method have been used not only with different species of animals but also with the same species. It is obvious that we can make no direct comparisons of the results obtained in these various situations. In general, the situations have been varied not with respect to single conditions but with respect to several conditions each of which seems to have a direct relation to the length of delay obtained. An examination of these studies indicates that the determining conditions include the method, direct or indirect, the mode of behavior for the animal permitted or favored by the experimental conditions, the species of animal studied, and especially when the indirect method is used, the number of choices offered to the animal, the criterion of proficiency which determines how long the animal will be trained on one period of delay before being advanced to a longer period as well as the criterion for satisfactory evidence of having attained the maximal length of delay that is reported.

III. DESCRIPTION OF ANIMALS USED

During the entire course of this study thirty albino rats (20 males and 10 females) were used. These were bred from animals selected at random from the colony used in the Department of Psychology at the University of Minnesota. The animals used in the experiment were taken from several litters and were marked and numbered when they were separated from the mothers. The

original numbers assigned to the rats are given in Table I under "original number." Later, to facilitate identification, the animals were assigned the numbers given in the column under

TABLE I

Table showing cues used, sex and age at starting on experiment

ORIGINAL NUMBER	EXPERIMENTAL NUMBER	SEX	AGE AT WHICH STARTED
			days
8	V-1	Male	72
9	K-1	Male	73
10	K-2	Male	74
11	V-2	Male	76
12	V-3	Female	91
13	K-3	Female	93
14	K-4	Female	104
15	V-4	Female	99
16	K-5	Female	132
17	A-1	Male	86
18	A-2	Male	86
19	A-3	Female	102
20	A-4	Female	102
21	V-5	Female	145
22	A-5	Male	81
23	V-6	Male	82
24	K-6	Female	149
25	K-7	Male	95
27	K-8	Female	105
29	V-7	Male	94
30	V-8	Male	94
31	V-9	Male	153
32	A-6	Male	153
33	A-7	Male	153
34	V-10	Male	153
	1	Male	100
	7	Male	98
	9	Male	125
	13	Male	96
	15	Male	200

"experimental number." We shall use these latter numbers in referring to them throughout this manuscript. The letters preceding the numerals refer to the type of cue used with the animal throughout the experiment, namely: A indicates auditory

cues; K indicates kinaesthetic cues; and V indicates visual cues. In those cases where no letter precedes the number of the animal, i.e., with nos. 1, 7, 9, 13, and 15, visual cues were used. All of the experimental animals were normal, healthy, vigorous rats and were maintained as such throughout the experiment except in a few cases where the animal had to be dropped due to having developed internal ear disease or some other sickness. The actual age in days when each animal was started on the problem is also included.

IV. APPARATUS AND GENERAL METHOD

A. Apparatus

The apparatus used in this experiment consisted of a box 22 inches in width and 140 inches in length and covered with wire netting of $\frac{1}{4}$ inch mesh. It was constructed of $\frac{1}{2}$ inch boards for all side and interior walls while the floor was made of regular 1 inch flooring. All side and interior walls were 6 inches high from the surface of the floor. The entire box was mounted upon legs 22 inches by 2 inches by 1 inch. This made a substantial piece of apparatus. The box consisted of six sections as shown in figures 1 and 2. Section A, consisting of the food box and the release box, R, was 12 inches long and 22 inches wide. The release box, which was 5 inches wide and 6 inches long, was placed against the middle portion of the wall separating Section A from Section B. The remainder of Section A served as the food box. From the release box, R, a sliding door (a) $3\frac{1}{2}$ inches in height and 4 inches in width served as an entrance from the release box to Section B of the apparatus. Entrance from the side alleys into the food box was effected by means of two doors (b and c) 3 inches wide and $2\frac{3}{4}$ inches high. These doors were made of tin and swung into the food box thus permitting the animal to enter the food box from the side alleys but not vice versa. These doors were swung from the top and each was equipped with a small bolt which held the door firmly closed when the animal was not to be permitted to enter the food box from that side.

The remainder of the apparatus consisted of sections B, C, D, E, and F. Each of these sections was divided by means of two walls, into three alleys, a middle alley 12 inches wide and two side alleys each 4 inches wide. Sections B and C were each 22 inches in length while Sections D, E and F were each 28 inches in length. The walls separating the alleys mentioned above were in each case 4 inches shorter than the length of the section of which they were a part. This arrangement gave two exits one into each

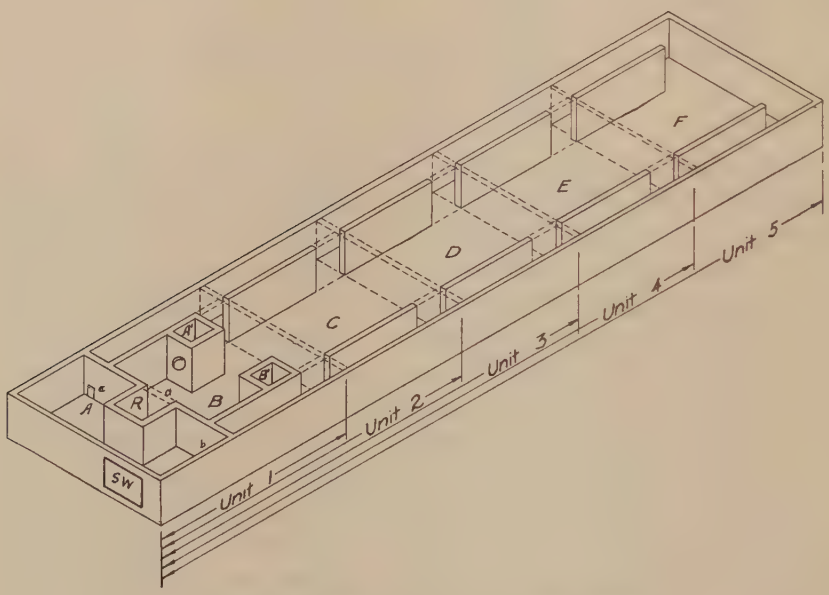

FIG. 1. PERSPECTIVE VIEW OF APPARATUS

side alley at the end of each section. These exits could, however, be closed easily by means of sliding doors which fitted evenly into the wall thus making the alleys continuous from Section B to the end of the apparatus in Section F.

In the middle alley of Section B were two boxes A′ and B′. These were stationary and were each 4 inches wide and 5 inches long and of the same height as the walls separating the alleys. As will be seen from the diagram, these boxes narrowed the middle alley from 12 inches to 4 inches at the point where the animal

had to "choose" the particular alley leading to the food compartment. Behind the boxes, were two narrow alleys 4 inches wide formed by the rear wall of the boxes and the wall separating Sections B and C.

The wall separating Sections B and C was movable and could be placed at will at the end of any section desired in the position indicated by the dotted lines in the diagram. When placed at the end of any section, all exits from the middle alley except those adjacent to the end-wall itself were closed by means of the sliding doors mentioned in the second paragraph of this section.

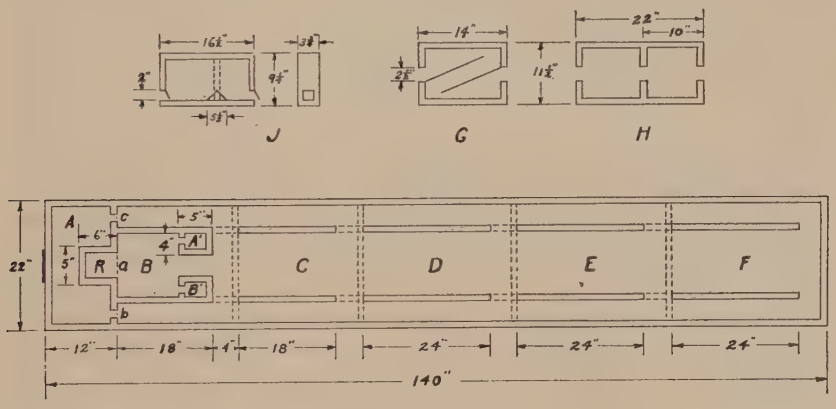

Fig. 2. Floor Plan of Apparatus

This movable wall made it possible to increase the alleys (both middle and side) to the following lengths. When the movable wall was at the end of Section B the middle alley (from the release box to the point where the animal had to "choose" the side alley leading to the food box) was 18 inches in length. When it was placed at the end of Section C the middle alley was 40 inches in length; of Section D 68 inches in length; of Section E, 96 inches in length; and of Section F, 124 inches in length. These distances were always measured to the middle point of the middle alley and 4 inches from the end-wall since the exits were 4 inches wide and the animal could leave the middle alley at any point within that distance.

Two additional parts of the apparatus (G and H) are shown at the side of Sections D and E respectively in the accompanying diagram. (G) was used for the purpose of (1) making more difficult or perhaps preventing the following, by the animal, of one or the other of the side walls in passing back through the middle alley; (2) breaking up any tendency which the animal might have to keep its body bent to one side when going down the middle alley; and (3) still further lengthening the path between the giving of the cue and the final "choice" of the side alley. It consisted of a box 14 inches long and $11\frac{1}{2}$ inches wide with an entrance $2\frac{1}{2}$ inches wide and 5 inches high at the middle of one end and an exit of the same size at the opposite end of the box. When it was in position in the apparatus, it fitted nicely into the middle alley, the floor of which also served as the floor of the box. Within the box were two walls each 11 inches long, made of tin and placed diagonally as shown in the diagram. These walls extended from the side of the entrance to the point $2\frac{1}{2}$ inches from the opposite side and the opposite end-wall thus causing the animal to bend its body sharply once toward each side in passing through the apparatus. Since the box was floorless, whether the animal was directed to the right or left on entering could be determined by merely inverting the box. In order to make this possible both the upper and lower ends of the entrance and the exit were semi-circular and placed so as to be raised $\frac{1}{2}$ inch from the floor.

Apparatus (H) shown in the diagram at the side of Section E was a box constructed of the same $\frac{1}{2}$ inch material as the rest of the apparatus. It was 22 inches long and $11\frac{1}{2}$ inches wide with a floor made of strong cardboard reinforced with tin strips. It was divided into two compartments by a cross-wall. The first of these compartments was 12 inches long while the second was 10 inches long. The entrance as well as the exit to this box consisted of a circular opening $2\frac{1}{2}$ inches in diameter which at its lowest point was $\frac{1}{2}$ inch above the floor. The opening in the wall between the two compartments was $2\frac{1}{2}$ inches wide and $2\frac{1}{2}$ inches high, the sides being straight and the top semi-circular. This box could be placed in the middle alley of Section D, E, or

F. Furthermore, it could be used with or without any additional impediment. As will be mentioned later on, with several animals, sand was piled up before the wall separating the compartments, hiding the opening and forcing the animal to dig through the sand before being able to reach the place where the path leading to food must be selected. The box without the sand compelled the animal to take a certain path at a certain part of the run, with sand in the box it accomplished the further purpose of forcing the animal to go through an additional series of movements and also lengthened the time of delay.

There now remain to be described certain pieces of apparatus that were used in presenting the cues to the animal, cues, on the basis of which the animal must make its selection of the path leading to the food. Of these, as stated previously, there were three, namely; visual, auditory, and a combination probably involving both the kinaesthetic and tactual senses. We shall describe these in order. The visual cues were supplied by means of two 15 Watt-120 Volt Mazda bulbs contained one in each light box (A′ and B′) in Section B. In the front side of each of these boxes was a circular opening $1\frac{1}{4}$ inches in diameter backed with opal glass. The current was obtained from the regular city current and was directed into the desired light by means of a double throw knife switch situated at the front of the apparatus. When auditory cues were used, they were supplied by means of a small electric buzzer fastened to the wall of the room in which the experimentation was done. This placed the buzzer to the left of the apparatus about 4 inches from it, on a level with it and about midway between the release box and the farther end of Section B of the apparatus. The current for the buzzer was supplied from a dry-cell battery. It was controlled by means of a knife switch fastened to the front of the apparatus itself. This was the only direct connection between the buzzer and the apparatus. The third type of cue could be supplied by means of the piece of apparatus (J) shown in the diagram. This consisted of a practically light tight box $16\frac{1}{2}$ inches long, $3\frac{3}{4}$ inches wide and $9\frac{1}{4}$ inches high. It was constructed of $\frac{1}{2}$ inch material and had all joints lined with felt. The entrance and exit consisted of

square openings 2 inches by 2 inches and located $\frac{1}{2}$ inch above the floor of the apparatus. The entrance and exit were closed by means of two tin swinging doors slightly larger than the openings which were lined with black felt. The felt prevented light from entering around the doors as well as serving to prevent noise caused by the doors' striking the wood after the rat had passed. The door at the entrance swung inward and upward being fastened to the inside of the box whereas the one at the exit was fastened to the outside and swung outward and upward. The lid of this box was removable and had attached to it two arms made of angle iron and extending from the lid to the floor. These arms fitted into two grooves one on each side of the inside of the box and just deep enough to present an even surface when the lid was in place. These grooves were located $5\frac{1}{4}$ inches from the farther end of the box. On the floor of this box could be placed a right angled incline which had a $5\frac{1}{2}$ inch base and which was $2\frac{3}{4}$ inches from the base to the apex. This increased the absolute length of path by $2\frac{1}{4}$ inches and in addition required the animal to ascend and descend an incline which was at the most a 45 degree angle. The incline was held stationary while in the box by means of a steel pin through the apex which fitted into two notches in the arms attached to the top of the box. When the incline was in position in the box, it fitted tightly on the floor and extended over the whole width of the box. The entire box when in position in the apparatus fitted into Section B and extended from the entrance of B back between and about an inch beyond the front of the light boxes.

In each side alley were kept two sets of grills each set covering the floor space of the alley for one section. These grills were moved with the movable end-wall so that if the apparatus was set for an alley longer than two sections the last two sections always had grills in them. The current for these grills was furnished from the city light current which was passed through a resistance coil and then through a small 110 Volt Bell Transformer (with primary and secondary reversed) before it reached the grills. The current could be directed into the grills on one side or the other as desired by means of a double-throw knife switch, again attached to the front of the apparatus.

All wooden and tin parts of the apparatus were painted black both inside and outside. The apparatus was placed in a room which could be darkened though it was not completely dark. The left side of the apparatus was adjacent to and only about four inches from the wall of the room. Directly above Section B was an indirect lighting fixture containing an electric light bulb (15 Watt) and covered by a paper shield to subdue the light still further. This was the only source of artificial light in the room while experimentation was going on except the light which was derived from the stimulus lights in the apparatus.

B. General method

The animals used in the experiment were kept in the regular animal room in the Psychological Laboratory. Each day before the experimentation took place all of the animals that were being used were taken to the experimental room at the same time and remained there until the conclusion of the day's experimentation. The experimental room was a rectangular room 13 feet, 6 inches in length and 7 feet, 6 inches in width and was located on the second floor of the laboratory. This necessitated carrying the animals quite a distance each time before the research for the day was conducted but they soon became accustomed to it and, in all probability, were not affected adversely by it. During the course of the experiment the animals were fed on the regular mash diet which has been in use at the University of Minnesota Psychological Laboratory.

The general method used throughout this research was as follows: Associations were first set up between some form of stimulus or cue, (i.e., a light, a sound, or certainki naestheticcues), certain movements when the end of the alley was reached and food. When the animal had learned to discriminate between the two forms of the cue used so that it went to the food box in the right direction when the appropriate stimulus was given, that is, when it had met the arbitrary criterion of such learning which we had set, the distance between the point where the cue could be received last and the end of the alley where the animal had to choose the alley leading to food was lengthened thus increasing

the length of the period of delay in making the final reaction to the stimulus originally given. When this length of alley had been mastered, again to the point where the animal met our criterion of learning, the alley was lengthened further, again increasing the period of delay. Our original plan was to continue this method of lengthening the path between the place where the cue was given and the place where the selection of paths had to be made, until we found a distance over which the animal could no longer learn to make the correct response to a given cue. It was soon discovered, however, that this would require a piece of apparatus longer than our space permitted. Consequently it was decided to train the animal in this manner until it reached the end of Section F of the apparatus and from that point increase the period of delay by the introduction into the middle alley of various impediments such as those described under "Apparatus G and H."

More specifically the actual training of the animal involved the following procedure. Several days before the actual training was to be begun the animal was taken to the experimental room and was placed in the apparatus and was permitted to explore the entire box for a short period. It was then fed in the food box. This was repeated on following days until the animal appeared to be reacting normally. All the swinging doors at the ends of the side alleys (and, when the box for giving the kinaesthetic cues was to be used on the animal, these swinging doors also) were kept open until the animal, when released from the release box, went through the apparatus to the food box without hesitation. The swinging doors were then put down and the animal was trained to go through these before it received food. When it had learned to do this without hesitation the regular training series were begun.

During the actual training series, the movable end-wall which fixed the length of alley was placed in the proper position then the animal to be trained was put in the food box of the apparatus. If the animal was to be given the cue to turn to the left for example, the small bolt holding the right door leading from the right side alley to the food box was pushed into position so as to

lock the door. The switch directing the current into the grills was set so that the current would flow into the grills on the right side of the apparatus. The animal was then placed in the release box, R, and after a few seconds the sliding door (a) was raised, releasing the animal. At the same time that the door was raised, if the stimulus was to be either an auditory or a visual stimulus, that stimulus was turned on by moving the knife switch at the front of the apparatus controlling the stimulus. If a kinaesthetic cue was to be given the box for that purpose described under "Apparatus" was put into position before the rat was placed in the food box. The apparatus was then set for the cue for the left turn at the end of the alley and the animal was released as described above. If at the end of the alley the animal turned to the left and came back the left alley he found the swinging door unbolted and was given food in the food box. If, however, he chose the right alley, he received a shock and, if he continued to the end of the alley found the door locked and had to retrace to the end of the alley, cross the middle alley and go out the alley on the left side only to receive no food. In either case, the doors and the grills were again adjusted for the next trial and the animal was put through the same process until it had received its required number of trials for that day. This was the procedure that was followed regularly except that after the discrimination had been set up and the alleys had been lengthened, if the cue was either auditory or visual, the stimulus was turned off at the moment that the animal reached the point in the alley between the light boxes A′ and B′. Furthermore, instead of turning the current into the grills before the animal was released, after the discrimination had once been set up and the alleys lengthened, the current was not directed into the grills at all unless the animal actually chose the wrong alley in which case the current was turned on the moment the animal stepped on the grill in the wrong alley. A careful record was kept of the correctness or incorrectness of the response, and, where the alley was lengthened, of the time consumed to the half second by the animal in going from the place where the stimulus was turned off to the point where he entered the side alley. This was done by means

of an ordinary stop watch which was started when the animal's body was between boxes A′ and B′. The watch was stopped when the animal indicated that it had made its choice by entering either side alley.

The experimental animals may be divided conveniently into three groups on the basis of the type of stimulus that was employed as a cue in the problem. With one group of animals a light stimulus determined the alley which was correct for the given trial and which, consequently, led to food. The stimulus in this case was given through the medium of the light boxes A′ B′ in Section B of the apparatus. If the light in A′ (on the left) was turned on when the animal was released, the opening in the front of the box backed by the opal glass appeared as a bright white circular area. This was the cue that the animal had to turn to the left in order to obtain food. If the lighted circular area appeared in the light box B′ the animal had to turn to the right at the end of the alley in order to obtain food when it reached the food box. With a second group of animals an auditory stimulus determined the alley which had to be selected if food was to be received in the food box. As previously pointed out under "Apparatus," this cue was supplied by means of a buzzer fastened to the wall of the room at the left side of the apparatus. If the buzzer was sounded as the animal was passing through Section B of the apparatus, it was the signal that the animal had to turn to the right at the end of the alley. If the buzzer was not sounded the animal had to turn to the left. The third group of animals were given a cue which differed from the first two groups in that the cue was intended to furnish a kinaesthetic cue rather than an auditory or visual stimulus. In order to present this cue to the animal, the piece of apparatus described as (J) under "Apparatus" was designed. As pointed out in that section the apparatus consisted of a box $16\frac{1}{2}$ inches long, $3\frac{3}{4}$ inches wide, and $9\frac{1}{4}$ inches high. It was practically light-tight with one door serving as an entrance and another as an exit and the animal passing through the box had to enter it immediately on leaving the release box. It had to pass through a swinging door at the entrance which closed immediately as the animal's body passed

through the entrance into the interior of the box. Here it had a straight narrow alley 15½ inches long with a swinging door at the other end. If this alley was unobstructed the animal had to turn to the left at the end of the path after it left the box. If, however, in passing through the dark narrow alley of the box, the animal encountered the 45 degree incline it had, on leaving the box, to turn to the right when it reached the end of the alley. Since the box in which this stimulus was presented to the animal was practically light-tight it is not likely that the animal was able to get any visual stimulation when in the box either when the incline was in position or when it was not there. In addition to being practically light-tight itself, the box when in position in the apparatus was so placed in Section B that the entrance of the box fitted tightly against the wall separating Sections A and B. Thus the only light which could reach the entrance of the box had to come through the release box. Considering that this was painted black and that the room was already darkened, it is extremely unlikely that any light entered it at all since when the animal was entering its body filled the opening and when it was in, the door closed immediately behind it. In all probability, the only cues that it could get were those of kinaesthesis and perhaps of tact. It might be possible that as the animal was passing through the alley it hit the incline with the tip of its nose and, after it had passed through several times, it was stimulated as the vibrissae came in contact with the incline and thus in both cases received tactual stimulation. It is quite certain, on the other hand, that the animal received kinaesthetic stimulation. If the incline was in position in the box, the animal had to climb over the incline before it could pass out at the exit of the box. This again would give the animal some tactual stimulation due to the unequal pressure on different feet, but in all probability, the greatest amount of stimulation came from the stimulation of the kinaesthetic sense as the animal climbed or ran over the incline. All of these of course were absent when the incline was not in the box. In learning the discrimination, the animal had to learn then that when they were present it had to turn to the right on leaving the box or when it reached the end of

the alley and to the left when they were absent. There is another possibility of stimulation which would differ in the two conditions. When the incline was absent the actual length of path which the animal had to traverse within the box was $15\frac{1}{2}$ inches. When the incline was in position the shortest possible length of alley was no longer $15\frac{1}{2}$ inches but the presence of the incline increased this distance by the length of the 45 degree incline and the 45 degree decline minus the length of the base. The length of the incline plus the length of the decline was $7\frac{3}{4}$ inches while the length of the base was $5\frac{1}{2}$ inches. The presence of the incline in the apparatus thus increased the length of path by $2\frac{1}{4}$ inches. This too should produce some difference in the amount of kinaesthetic stimulation which the animal would receive under the two conditions. Since it is certain that kinaesthetic stimulation differed under the two conditions we shall hereafter refer to these cues as kinaesthetic.

From the foregoing it will be quite evident that the three groups of animals had to set up discriminations under conditions which were not exactly comparable. In the case of the animals receiving visual cues the animals had to discriminate not between the presence and absence of a particular stimulation but rather between the position from which that stimulation was derived. In the case of the visual cues this difference of position amounted to a difference of 8 inches from the center of the one stimulus to the center of the other. Or looking at the same thing from another viewpoint if the light came from the right of the animal, it had to turn to that side; if from the left, it had to turn to the left. It always had to turn toward the side from which the stimulation had come. In other words, a light was present each time that the animal passed through the apparatus. In the case of the group receiving the auditory cues this was not the case. Here the animal had to learn that the presence of the sound of the buzzer meant that the animal was to make one series of movements while the absence of that sound meant the making of another series of movements or turning to the opposite side. When the sound stimulus was used the animal had to turn not toward the side from which the stimulation came but away

from it. In the case of the animals receiving the kinaesthetic cues the animal again had to discriminate between the presence or absence of additional stimulation. Here the animal had to turn to the one side when the additional stimulations were present and to the opposite side when they were absent.

The animals of each group were given ten trials daily throughout the entire period of training. These trials followed one after the other with a short interval between trials. The experimentation throughout was done in the late afternoon between 3 and 6 o'clock for the most part. Furthermore, after an animal was once started, it was run at about the same time each day. This was possible by beginning experimentation promptly at a regular time and then running the animals each day in the same order.

Throughout the training the series of trials (whether the cue to turn to the left or to the right was to be given) was changed frequently in order to prevent the animal from learning the series.

One more point remains to be considered under the heading of "General Method." This is the question of how many or what percentage of correct choices shall be taken as sufficient to justify our saying that the animal has learned the discrimination, or as sufficient to justify moving the animal on to a longer period of delay. With only two possible choices of alley leading to the food box, pure chance should cause the animal to make 50 per cent correct choices over a long series of trials. But rarely in experimentation are a sufficient number of choices made for chance to operate as it should theoretically. If, however, we make the series sufficiently long and in addition to that require the animal to make a sufficiently high percentage of correct choices over a limited length of series we can be sure that the animal has learned the problem and is not merely reacting by chance. In this experiment we arbitrarily set the length of the series of trials at 40 (ten on each of four successive days) and set our standard of having learned at 85 per cent correct choices over the four days with no less than 80 per cent correct choices on any one of the four days. The animal might now react 85 per cent of the time correctly over the four day period but if any one of

the four days averaged less than 80 per cent correct the animal was not said to have learned the discrimination or the particular period of delay on which it happened to be and consequently was continued until it finally did reach our criterion.

In December 1928 the training of the animals, 1, 7, 9 and 13 was begun using a somewhat different method from that used with the aforementioned animals. The method with these animals consisted of setting up a discrimination with light as a stimulus in exactly the same manner as in the case of the animals designated by V (and the number of the animal), except that with these four animals fifteen trials were given per day. After the discrimination had been set up the animal was advanced to the part of the apparatus which necessitated a delay between the giving of the stimulus and the point where the choice of alley had to be made, but here, instead of advancing the animal unit by unit as the separate units were mastered, an attempt was made to set up the four units involving delay periods simultaneously. In order to do this after the discrimination had been set up, the animal was given 15 trials per day as follows: three trials on the discrimination followed by three trials on each of the four units to the end of the apparatus. Here, as with the preceding animals, one trial followed after the other with a brief period intervening. A somewhat longer interval intervened between the last trial on one unit and the first trial on the next unit than between the trials within the same unit in order to permit the experimenter to make the necessary alterations of the apparatus for the trials on the next longer unit.

With this group of animals we considered the discrimination set up when the animal had on three successive days (45 trials) made an average of at least 85 per cent correct choices with no single day having less than 80 per cent correct. In the units involving a period of delay the animal was to be continued in training until the responses on all units reached a sufficiently high percentage of responses to show that all were learned. In all other respects these animals were treated as were the others.

In March 1929 animal 15 was started on the problem under exactly the same conditions and with the same method except

that the stimulus for turning to the right consisted of one light in each light box while the stimulus for turning to the left was the absence of light in both boxes. In all other respects this animal's training was similar to that of the preceding four animals.

C. Controls exercised

One of the criticisms (Watson (20, p. 225)) that has been urged against the experiments on delayed reaction performed by Hunter has been that he did not control sufficiently the possibility that the box in which the light last appeared might have risen in temperature and again that even if the rise in temperature had not been sufficient for the animal to select on that basis the correct box yet the rise might have been sufficient to increase "the diffusion of gaseous particles which arouse the olfactory receptors" and give the animal a basis for its selection of the box. Of course in such a case no delayed reaction would be present but it would merely be a case of discrimination on the basis of the temperature or the olfactory sense or perhaps of a combination of the two. Due to the method and apparatus used in this research such possibilities were entirely avoided. Furthermore, if they were present at all in the first part of the training in the present problem they became more remote the further the animal progressed in the problem. Here the animal had to make the final reaction in the middle alley at a point where the light had never been.

Nor was it possible in this study that the animal could get any olfactory cue from the food which was used to reward the animal after a correct choice. In all cases the animal was fed in the food box and there only at the middle of the box directly in line with the middle of the release box and against the wall of the food box opposite that against which the release box was placed. Under the existing conditions any odor which the food might possibly have given off would have diffused equally into both alleys.

Neither could the animal get other olfactory cues for the only other possible ones would be the scent from its own body re-

maining stronger in the alley last used than in the other alley. If the animal were reacting on such a basis either a position habit of always going to the one side or a simple alternation habit would result. Either of these possibilities would mean that the animal could never meet the required criterion because the series used were always chosen so as to preclude such possibilities.

No possibility of the animal receiving a cue as to the correct alley to enter was possible as far as the grills in the side alleys were concerned. As has been previously stated the current in the grills was controlled by means of a switch at the front of the apparatus. As a result it was possible to direct the current into the grill desired immediately when the animal entered the wrong alley. As a result the animal had to make its selection of alley and enter it before any current was in the grill to serve as a cue.

Another possibility that needs to be controlled in animal experiments is that the animal may receive cues as to the correct response from the experimenter himself. Again the possibility of the animal's receiving such cues in this problem was rather remote. As far as visual cues are concerned, it has already been stated that the room was darkened. Furthermore, at no time when a period of delay was involved was the animal closer to the experimenter than 64 inches or over 5 feet and as he advanced further in the problem this distance increased until, when the animal reached the further end of the apparatus. it was at least 12 feet from the experimenter. It is not probable that the animal could get any visual cues from the experimenter at any of these distances. The animals were, however, tested at various times for this factor by placing a heavy cardboard screen between the experimenter and the apparatus. Under these conditions the animals reacted about the same as when the screen was absent, consequently the above suppositions appear correct. Furthermore, the behavior of the animals when they reached the end of the middle alley was such that it was highly improbable that they could be reacting to any auditory cues such as they might receive from the experimenter's breathing rate and so on.

One more possibility remains to be discussed under the general heading of Controls. That is the possibility that whenever a

delay was involved the animal made the discrimination in Section B of the apparatus all right but then followed either the right or the left wall of the middle alley to the end of the alley and then turned into the side alley on that side of the apparatus. That this was a real possibility was definitely shown by a number of the animals. In the early trials, on some sections of the apparatus, they definitely showed this form of behavior. After the first few trials on the section, however, this disappeared and the animal followed the same path in the alley irrespective of the cue that was given in Section B. Yet even this behavior did not preclude the possibility that the animal was following the wall on either side of the apparatus, for example, it might have continued looking at the wall toward which it had to turn when it reached the end of the alley. Though we could not entirely eliminate this possibility yet we could increase the difficulty of so doing. In attempt to effect such an increase in difficulty the apparatus (G) described under "Apparatus" was designed. This practically reversed the path of the animal for a short distance and, while it still did not eliminate the above possibility yet it certainly did add a confusing element to the situation. As is pointed out later the behavior of the animal while in the problem indicated that it was not following the side walls while going through the middle alley.

V. EXPERIMENTAL RESULTS

A. Setting-up the discrimination

As was mentioned before the experimental animals were divided into three groups:

(A) Those animals which were trained to respond to a light stimulus;

(B) Those animals which were trained to respond to a sound stimulus; and

(C) Those animals which were trained to respond to the presence or the absence of the incline.

Group (A) may further be divided into two sets of animals: (1) those receiving ten trials per day, and (2) those receiving 15 trials per day. Ten animals were used in Set 1 of Group A.

Set 2 of Group A consisted of 5 animals. These will be considered presently. Group B consisted of 7 animals and Group C of 8 animals. The various animals composing each group are designated in the following tables by V (and the number of the animal) for those animals trained to respond to the light stimulus; A (and the number of the animal) for those trained to respond to the sound stimulus; and K (and the number of the animal) for those trained to respond to the incline plane.

Table II gives the number of trials required for setting up the discrimination to the point where the individual animal met our criterion of learning which as stated previously was that the animal make at least 85 per cent correct responses over four consecutive days with no less than 80 per cent correct choices on any one of the four days. In addition to the number of trials required to attain this criterion, it also gives the percentage of correct choices made over the four day period. The records given in Table II are for only those rats which were given ten trials per day.

From the foregoing table it may be seen that all the animals learned the discrimination upon which they were being trained with the exception of rats K-2 and K-5. In the case of K-2 the animal averaged 45 per cent correct responses over the last 4 days training and 50.2 per cent over the entire 830 trials on the discrimination. At no time during the entire learning did this animal average more than 60 per cent correct over a four day period. During the greater part of the training the animal exhibited a position habit of always running into the right alley which probably accounted for its lack of improvement in learning the discrimination. At the end of the designated number of trials the animal was dropped from the problem. In the case of K-5, the average over the last 4 days was $52\frac{1}{2}$ per cent and the average over the entire 240 trials was $55\frac{1}{2}$ per cent. This animal was in very poor physical condition and since she was showing no progress, in all probability due to that factor, she was disposed of.

An examination of Table II will reveal a decided difference in the number of trials required by each group to learn the discrimination. Thus Group A which was trained to discriminate on the basis of light required on the average (median) 405 trials

to meet our criterion; Group B trained to discriminate on the basis of auditory stimulation required a median of 210 trials; while Group C, trained to discriminate on the basis of the presence or absence of the inclined plane required on the average

TABLE II

Table showing the number of trials required for learning the discrimination and the percentage correct over the last four days

	RAT	NUMBER OF TRIALS FOR LEARNING	AVERAGE PER CENT CORRECT OVER LAST FOUR DAYS
Group A	V-1	670	85
	V-2	970	85
	V-3	720	87½
	V-4	620	85
	V-5	180	87½
	V-6	710	90
	V-7	190	87½
	V-8	150	90
	V-9	140	90
	V-10	170	90
Group B	A-1	410	87½
	A-2	180	87½
	A-3	210	85
	A-4	350	87½
	A-5	240	85
	A-6	200	87½
	A-7	180	85
Group C	K-1	1,300	87½
	K-2	830	45
	K-3	1,200	85
	K-4	1,460	85
	K-5	240	52½
	K-6	890	100
	K-7	770	85
	K-8	600	90

1045 trials. This difference is, however, not to be explained entirely on the difference in difficulty between the three types of cues. These differences can be accounted for in part by the fact that punishment was not introduced at the same point in the learning for all rats. The first eight rats which were trained on

the discrimination were started without punishment, some of them having 600 trials in this manner. It then became evident that, if the discrimination was to be set up within a reasonable number of trials, punishment must be used. Accordingly it was introduced. With all other animals used in the experiment punishment was introduced on the sixth day, i.e., after the fiftieth trial. Table III shows for the animals with which punishment was not introduced on the sixth day, the number of trials each animal was run without punishment and the percentage correct over those trials; the number of trials with punishment, necessary to set up the discrimination and the percentage correct over

TABLE III

Table showing number of trials with and without punishment and records over those trials for those animals given more than 50 trials without punishment

RAT	NUMBER OF TRIALS WITHOUT PUNISHMENT	PER CENT CORRECT WITHOUT PUNISHMENT	NUMBER OF TRIALS WITH PUNISHMENT	PER CENT CORRECT WITH PUNISHMENT	TOTAL NUMBER OF TRIALS	PER CENT CORRECT FOR ALL TRIALS	PER CENT CORRECT OVER LAST 40 TRIALS
V-1	350	59.7	320	63.4	670	61.5	85
V-2	600	62	370	69.4	970	64.8	85
V-3	400	53.2	320	68.7	720	60.1	87.5
V-4	400	49	220	73.1	620	57.6	85
K-1	600	62	700	64.5	1,300	63.4	87.5
K-2	600	50	230	50.8	830	50.2	45
K-3	400	48	800	61.8	1,200	57.1	85
K-4	300	49.3	1,160	60.6	1,460	58.2	85

those trials; and the total number of trials necessary to set up the discrimination and the percentage correct over the total learning as well as the percentage correct over the last 40 trials.

If we eliminate the above animals and consider only those with which punishment was introduced on the sixth day of training, in other words after the fiftieth trial, we find that the median number of trials required for setting up the discrimination becomes 175 for Group A and 770 for Group C. The difference between the median number of trials required by Groups A and B, whether we include all the animals in group A or exclude those that were trained for a longer period without

punishment, is not sufficiently reliable to make possible any definite conclusion as to the relative ease of establishing the discrimination to a visual and to an auditory stimulus. The cases are too few, the differences which do appear are inconsistent in direction and the group which were trained without punishment were all trained on the visual cue and all required a relatively long time after the introduction of punishment to meet our criterion for the discrimination. However, from the fact that for three animals the visual discrimination was established in fewer trials than were required by the best of the animals to learn the auditory discrimination, there is some evidence that the visual discrimination may be set up somewhat more easily. The three best animals learning the visual discrimination required 140, 150, and 170 trials respectively with 90 per cent correct over the last forty trials in each case; while the two best animals learning the auditory discrimination required 180 trials each with $87\frac{1}{2}$ and 85 per cent correct respectively.

In the case of the animals in which the kinaesthetic cue was used there is little doubt but that the discrimination was established much less readily than in the case of the animals in which the visual and the auditory cues were used. The median number of trials for establishing the discrimination to the kinaesthetic cues, when we include only those animals in which punishment was introduced after 50 trials, is 770 and the best animal in that group required 600 trials to learn it, the percentage correct over the last 40 trials being 90.

Another factor which may account in part for the difference in the rate of learning between the visual and auditory groups is that in the case of the group given the visual cues the stimulus was to turn toward the side on which the light appeared. In the case of the other group, the auditory group, the animal turned to one side when the stimulus was present and to the other side when the stimulus was absent. Thus the visual group could react in part on the basis not only of light but of light plus position or location of light. With the animals using the auditory stimulus no such reactions on the basis of position was possible. While the writer is unaware of other experimental evi-

dence on this question yet one would expect that it would be a factor influencing the learning. As far as the animals trained on the kinaesthetic cues, or the inclined plane, are concerned, reaction on the basis of position was again out of the question because both cues, either presence or absence of the incline, were received at the same point in space, that is in the same position.

As pointed out above, five animals (Set 2, Group A) which were trained to discriminate on the basis of visual stimuli were given 15 trials instead of 10 trials per day. For four of these animals numbers 1, 7, 9, and 13 the light stimulus was presented under exactly the same conditions as for Set 1 under Group A. Punishment in the training of this set of animals was introduced on the fourth day, i.e., after the forty-fifth trial. This made the

TABLE IV

Table showing the number of trials and the percentage correct over the last 45 trials for rats receiving 15 trials per day

RAT NUMBER	NUMBER OF TRIALS ON LEARNING	AVERAGE PER CENT CORRECT OVER LAST 45 TRIALS
1	270	87
7	525	89
9	255	89
13	195	91

animals in this set and in Set 1 comparable as to the method of presentation of the stimulus and practically so as to the time of the introduction of punishment. The results for these animals are given in Table IV.

From the above table it may be seen that these animals required a slightly greater number of trials to learn the discrimination than did the animals trained under similar conditions but having only ten trials per day. The median here is $262\frac{1}{2}$ trials as compared with the 175 trials for the animals having ten trials per day. This is in agreement with the results found in other investigations, viz., that the smaller number of trials per day is more economical with respect to the number of trials required for the learning. In this case, however, the number of days required to set up the discrimination was about equal in both cases.

In an attempt to make the visual cue more nearly comparable with the auditory cue the discrimination between light and the absence of light was set up with one animal. In this case both of the lights in Section B of the apparatus were turned on as the cue for the animal to turn into the right alley, while the absence of light was the cue to turn into the left alley. As it was not intended to use this animal in the regular experiments but only to set up the discrimination in order to compare, for our own information, this method of setting up a visual discrimination with the single light method and with the method of setting up the auditory discrimination, an animal which was considerably older than the other animals was used. When, however, we found that the animal learned the discrimination with unexpected ease and rapidity, we decided to retain the animal for further training, i.e., for training on the delay. The record of this animal in learning the discrimination follows. The discrimination was set up in 7 days with a total of 105 trials which is considerably less than was required by any other of the experimental animals. The percentages of correct trials for each of the seven days of 15 trials each were as follows: 47, 53, 47, 67, 100, 100, 100.

B. Training involving a period of delay

After the discrimination had been set up, as pointed out previously, the training involving a period of delay was undertaken. Again, as noted previously, the discrimination was set up using only that part of the apparatus designated under "Apparatus" as Sections A and B or unit 1, i.e., the food and release box, and the section in which the stimulus was presented. For convenience, the training involving only Sections A and B will, hereafter, be referred to as Stage I of the training. When the apparatus was lengthened so as to make Sections A, B, and C a unit, we shall refer to the training on this unit as Stage II. Likewise, when Sections D, E, and F were added in order and cumulatively to the stage II unit, we shall refer to the training involved as Stages III, IV, and V respectively. As may be seen from the diagram in the Section under "Apparatus," Stage II involved training over a path increased by 22 inches from the point where

the selection of the path had to take place in Stage I of the training. Whereas, in Stages III, IV and V the path was increased by 50, 78, and 106 inches respectively over that of Stage I.

The training, involving the delay, may conveniently be divided into two parts (1) that involving the straight unimpeded central pathway of Stages II, III, IV, and V, and (2) that involving the additional apparatus designed to increase the complexity of the problem as indicated under "Apparatus." The results reported first will include only those on Stages completed with the central alley unimpeded or up to and including Stage V. Furthermore, for the present we shall deal only with those animals which received ten trials per day throughout the training.

1. Training involving a straight unimpeded central pathway: Group differences as shown by: (a) The best stage reached. Not all the animals using the different types of stimuli reached and completed (that is met our criterion on) the same number of Stages of the training. Table V shows for the three groups of animals trained on the visual, the auditory and the kinaesthetic stimuli, the stage completed by each animal, the percentage of correct responses over the last forty trials and the total number of trials given each animal with the central pathway unimpeded.

As may readily be seen from Table V, differences, as far as the stage attained was concerned, appeared between the various groups of animals. Thus four animals in Group A never completed more than Stage II; four animals completed Stage III; and two animals completed Stage IV. In the group trained with auditory stimuli, Group B, one of the animals completed only Stage II; one completed Stage III; one completed Stage IV and four animals of this group reached and completed Stage V. In the case of Group C it may be seen that two of the animals, for reasons mentioned previously, never completed Stage 1; one animal completed Stage I but never met the criterion on a higher stage; three animals completed Stage II and two animals completed Stage III. When we compare the total number of trials given to each group and the stage successfully completed in that amount of training it is evident that the groups rank in

order of success in the problem as follows: (1) auditory, (2) visual, and (3) kinaesthetic.

b. The number of trials necessary to attain the highest stage. Another line of evidence which indicates differences between groups

TABLE V

Table showing the final stage of the apparatus completed by the animals of each group

	RAT NUMBER	STAGE	PER CENT CORRECT OVER THE LAST FOUR DAYS	TOTAL NUMBER OF TRIALS GIVEN THE ANIMAL ON THE UNIMPEDED PATHWAY
Group A	V-1	II	92½	2,010
	V-2	II	87½	4,610
	V-3	II	85	1,400
	V-4	III	85	2,360
	V-5	IV	85	3,360
	V-6	III	85	1,600
	V-7	III	87½	1,910
	V-8	II	92½	1,910
	V-9	IV	85	450
	V-10	III	85	560
Group B	A-1	V	85	1,120
	A-2	V	85	1,030
	A-3	III	95	1,400
	A-4	V	90	2,090
	A-5	V	97½	820
	A-6	II	92½	360
	A-7	IV	90	470
Group C	K-1	II	85	4,440
	K-2			830
	K-3	II	90	3,790
	K-4	I	92½	4,020
	K-5			240
	K-6	III	87½	3,030
	K-7	III	85	1,610
	K-8	II	85	1,660

receiving the different types of cue used, is that of the number of trials required by the various animals in each group to complete the stages on which the animal met our arbitrary criterion of learning. In Table VI are tabulated the number of trials re-

quired by each animal of each group to meet the criterion on each stage which the animal completed successfully. In the second column under the various stages are shown the percentages of

TABLE VI

Table showing the number of trials required to complete each stage of the apparatus and the total number of trials required to attain the highest stage reached

	RAT	I		II		III		IV		V		TRIALS
		Trials	Per cent	Trials	Per cent	Trials	Per cent	Trials	Per cent	Trials	Per cent	
Group A	V-1	670	85	630	92½							1,300
	V-2	970	85	1,500	87½							2,470
	V-3	720	87½	110	85							830
	V-4	620	85	840	85	590	85					2,050
	V-5	180	87½	740	87½	1,020	87½	1,030	85			2,970
	V-6	710	90	350	87½	540	85					1,600
	V-7	190	87½	50	85	740	87½					980
	V-8	150	90	70	92½							220
	V-9	140	90	110	87½	150	90	50	85			450
	V-10	170	90	90	87½	120	85					380
Group B	A-1	410	87½	110	85	80	85	150	90	370	85	1,120
	A-2	180	87½	40	85	670	90	90	85	50	85	1,030
	A-3	210	85	670	90	390	95					1,270
	A-4	350	87½	360	85	450	85	870	90	60	90	2,090
	A-5	240	85	80	87½	300	92½	70	90	130	97½	820
	A-6	200	87½	60	92½							260
	A-7	180	85	90	85	150	85	50	90			470
Group C	K-1	1,300	87½	930	85							2,230
	K-2											
	K-3	1,200	85	1,290	90							2,490
	K-4	1,460	85									1,460
	K-5											
	K-6	890	100	280	87½	1,860	87½					3,030
	K-7	770	85	390	85	220	85					1,380
	K-8	600	90	690	85							1,290

correct choices which that animal made over the four day period on which it met the criterion. In the last column of the table are given the total number of trials required by the animal from the beginning of its training, i.e., from the beginning of learning

the discrimination, to the point where it met the criterion on the highest stage of the five which it completed.

It was sometimes necessary in the course of training to return an animal for a short period to a stage which it had previously successfully completed. Whenever such was the case those

TABLE VII

Table showing for each animal the cumulative number of trials for each stage completed

	RAT	I	II	III	IV	V
Group A	V-1	670	1,300			
	V-2	970	2,470			
	V-3	720	830			
	V-4	620	1,460	2,050		
	V-5	180	920	1,940	2,970	
	V-6	710	1,060	1,600		
	V-7	190	240	980		
	V-8	150	220			
	V-9	140	250	400	450	
	V-10	170	260	380		
Group B	A-1	410	520	600	750	1,120
	A-2	180	220	890	980	1,030
	A-3	210	880	1,270		
	A-4	350	710	1,160	2,030	2,090
	A-5	240	320	620	690	820
	A-6	200	260			
	A-7	180	270	420	470	
Group C	K-1	1,300	2,230			
	K-2					
	K-3	1,200	2,490			
	K-4	1,460				
	K-5					
	K-6	890	1,170	3,030		
	K-7	770	1,160	1,380		
	K-8	600	1,290			

trials on that earlier stage were not included in the number of trials shown in Table VI.

In Table VII are shown the same data on the number of trials required as are shown in Table VI, except that they are arranged cumulatively, i.e., include with the trials on any given stage the trials on all previously completed stages.

A consideration of the median number of trials required by each group of animals to meet the criterion on each stage, as obtained from Table VI shows us that for Stage II, the first in which a period of delay was introduced, those trained with the visual cue required 230 trials; those with the auditory cue 90 trials; and those with kinaesthetic cue 690 trials. If we use the median of the cumulative number of trials, i.e., include those trials on Stage I with those on Stage II, as obtained from Table VII, the medians for the three groups are: Visual 545; Auditory 295; and Kinaesthetic 1290. If we exclude those animals which were trained for a long period without punishment on Stage I, as was described in an earlier part of this Section, we find that the differences between the medians on Stage II decrease but remain in the same direction. The median number of trials for Group A is 110; for Group B 90; and for Group C 390. The differences, however, when we consider the cumulative trials, are changed in direction somewhat. The median for Group A is 245, for Group B is 295 and for Group C is 1170. The explanation for the inversion of Groups A and B lies in the fact that, with the exclusion of the four animals trained on the discrimination in part without punishment, the group trained on the visual cue made a slightly better record on Stage I than did the group trained on the Auditory cue. The difference was great enough to obscure the better record of the Auditory group on Stage II.

The number of animals included in the three groups on Stage III is somewhat smaller than the number on Stage II since four of the animals in Group A, one in Group B and three in Group C completed Stage II but not Stage III. The differences between the medians of the number of trials required by the three groups on Stage III are in the same direction regardless of the method of obtaining them. Using only the trials on Stage III we find that Group A required a median of 565 trials, Group B 345 trials and Group C 940 (obtained from two animals with 1860 and 220 trials respectively). Using cumulative trials we find a median of 1290 for group A; of 755 for Group B and above 1380 trials (the number of trials by the best rat) for Group C. Excluding the one rat in Group A trained without punishment which reached

Stage III, the median for Group A is 540 on Stage III alone and 980 for the cumulative trials. Both of these medians are higher than those for Group B and less than those for Group C.

On Stages IV and V too few animals are represented in any group except the Auditory Group to make any comparisons other than to say that it is obvious that the record of the Auditory Group in regard to trials, is superior to those of the other groups. If we compare the median number of trials given the animals of the three groups in which they either did or could have completed the five stages in which the central pathway was unimpeded (See final column Table V, p. 51), we find that the median number of trials for Group A is 1910, for Group B is 1030 and for Group C is 2345. Thus it may be seen that if animals from Groups A and C had completed the five stages, the median number of trials required to do so would have been greatly in excess of that required by Group B.

c. Delay period attained. A third indication of evidence corroborating group differences is found in a consideration of the median length of delay for each rat on the completed stages. The median length of delay considered here is the median delay on only the correct responses made during the forty trials during which the animal met the criterion for the given stage. These medians are shown in Table VIII.

The difference between the three groups in the length of the delay period appear to be greatest in Stage II. In that Stage the groups would seem to maintain the same rank order, using the longest delay period as best, that they showed in regard to the highest stage reached and the fewness of trials required successfully to complete each stage. Four of the seven animals in the Auditory Group had median delay periods of 2 seconds while the remaining three had delay periods of $1\frac{1}{2}$ seconds. In the Visual Group only three of the ten animals delayed 2 seconds and the remaining animals delayed $1\frac{1}{2}$ seconds. On the other hand, we find that in the Kinaesthetic Group two of the five animals delayed 2 seconds, one delayed $1\frac{1}{2}$ seconds and two delayed only 1 second.

In all other stages either the number of cases is too small or

no differences are apparent except that all but one of the four animals from Group B which completed Stage V attained a median delay period on that Stage of $3\frac{1}{2}$ seconds while only one

TABLE VIII

Table showing for each rat the median length of delay in seconds (correct responses only) during the four-day period in which the animal met the criterion of each stage

	RAT	II	III	IV	V
Group A	V-1	2			
	V-2	$1\frac{1}{2}$			
	V-3	$1\frac{1}{2}$			
	V-4	2	2		
	V-5	$1\frac{1}{2}$	2	$3\frac{1}{2}$	
	V-6	$1\frac{1}{2}$	3		
	V-7	2	2		
	V-8	$1\frac{1}{2}$			
	V-9	$1\frac{1}{2}$	$2\frac{1}{2}$	3	
	V-10	$1\frac{1}{2}$	2		
Group B	A-1	2	2	2	3
	A-2	$1\frac{1}{2}$	2	3	$3\frac{1}{2}$
	A-3	2	3		
	A-4	2	2	3	$3\frac{1}{2}$
	A-5	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$
	A-6	$1\frac{1}{2}$			
	A-7	$1\frac{1}{2}$	2	3	
Group C	K-1	2			
	K-2				
	K-3	1			
	K-4				
	K-5				
	K-6	$1\frac{1}{2}$	2		
	K-7	1	2		
	K-8	2			

animal (V-5) from either of the other groups attained a median delay of equal length on any completed stage.

From an examination of Tables VI, VII and VIII, it is evident that while there are consistent differences between the groups as shown by the medians of the number of trials, yet the differences within the groups are equally marked. These intra-

group differences are especially marked in Group A, somewhat less marked in Group C and much less evident in Group B. In Group A is found the animal (V-9) which up to the time when its training was unavoidably interrupted and discontinued had made the best record of any animal up to that point.[3] It is unfortunate that the training of this animal could not be continued for we have reason to believe on the basis of its record over the first four stages that it not only could have completed the five stages under consideration here, but would have advanced into the training involving at least some of the additional apparatus. In this group we find also on each stage involving delay an animal which shows either the poorest record or next to the poorest record of any animal in the three groups trained on that stage. While the number of trials required by the animals in Group C was in every case except one, above the median for the three groups yet the range of the number of trials for this group greatly exceeded the highest number of trials required by any one animal in Group B. In both Groups A and C, some individual animal required trials in excess of 1000 to meet the criterion on each of the completed stages involving delay; in contrast to this we find that no animal in Group B exceeded 870 trials to master any stage.

If we now consider those stages on which the animals received training without meeting our criterion, we find as shown in Table IX, that 16 of the 25 animals will be represented. For one animal the stage on which the uncompleted training was given was Stage II, for eight it was Stage III, for five it was Stage IV, and for two it was Stage V. Although for the last four days of training none of these animals showed a percentage of correct responses higher than 75 and that percentage in only two cases, yet for all except three of the animals the responses over the best four days showed 75 per cent or above and in three of the cases the per-

[3] The training of Animals V-9, V-10 and A-7 was begun on June 2, 1928 in order to increase the number of animals trained on the first few stages. It was discontinued at the end of July due to the necessary absence of the experimenter from the laboratory. A-6 was started on the problem at the same time as the other three animals but died about the middle of July.

centage correct was 85 without meeting our criterion since on one of the four days the percentage had fallen below 80. These animals all show evidence of learning on the stages represented and, had our criterion for mastering the stage been slightly lower, most of these animals would have met it.

2. Training involving an impeded central pathway. The experiment was planned to include the introduction into the central

TABLE IX

Showing the results of training for those animals which received training without meeting our criterion on any of the first five stages

RAT NUMBER	STAGE	NUMBER OF TRIALS ON STAGE	LAST FOUR DAYS		BEST FOUR CONSECUTIVE DAYS	
			Per cent correct	Median delay	Per cent correct	Median delay
				seconds		*seconds*
V-1	III	710	55	4	77½	2½
V-2	III	2,140	57½	3½	82½	3
V-3	III	570	45	2	75	2
V-4	IV	310	60	5	77½	3
V-5	V	910	62½	5	82½	6½
V-7	IV	930	75	3¼	82½	3
V-8	III	1,690	55	3	77½	3
V-10	IV	180	47½	3	62½	3½
A-3	IV	130	55	7	67½	6
A-6	III	100	75	2½	85	2½
K-1	III	2,210	57½	3	82½	3
K-3	III	1,300	72½	2	85	2
K-4	II	2,560	62½	1½	85	2
K-6	IV	960	67½	3½	75	3½
K-7	V	290	57½	3	70	3
K-8	III	370	57½	2½	80	3

pathway of various impediments (some of which are described as auxiliary sections under "Apparatus") as soon as the training of the animal on the first five stages had been completed. Not all of the animals included in the experiment received this additional training for the simple reason that the majority failed to advance sufficiently far to warrant its introduction. All of those animals which reached Stage V received at least some of this additional

training, and some of the other animals, which will be mentioned below, also received training on some parts of the additional apparatus before they had reached Stage V.

The first attempt to place an impediment in the central alley consisted of placing in it a very simple addition which would compel the animal to follow a somewhat different path there from that it had previously followed by its own selection. This consisted merely of two boards of 12 inches long and 6 inches high, placed crosswise and 4 inches apart in the middle of Section D of the apparatus. The animal had to pass through centrally located openings in the boards $2\frac{1}{2}$ inches wide by 5 inches high. The training involved with the introduction of this addition to the apparatus constitutes Stage VI. This stage differs from Stage V only by the inclusion of this impediment.

Three animals (A-1, A-2, A-5) were tested with this arrangement and completed the stage in a relatively short time, requiring only 50, 110 and 160 trials respectively with 85, 85 and $87\frac{1}{2}$ per cent correct responses over the last four days on the stage. Previously two of these animals, A-1 and A-2 had been running along the left side of the central pathway while the third, A-5, had been running along the right side, regardless of the cue given. The introduction of the two boards, of necessity interfered with those habits since the animal now had to go through the middle of the central pathway for at least 4 inches in Section D. This interference in the habitual reaction did not disrupt to any great degree the animal's ability to make the correct choice even though it increased the median period of delay over the last four days for A-2 from $3\frac{1}{2}$ seconds to $4\frac{1}{2}$ seconds and for A-5 from $3\frac{1}{2}$ seconds to 4 seconds. The median time of delay remained the same for A-1 which may afford a partial explanation for the smaller number of trials required by this animal to meet the criterion. When the boards were in position, A-1 showed a greater tendency to run through the middle of the central pathway throughout its entire length, whereas the other two animals still tended to run to the favored side up to the point where the boards compelled the animals to run in the middle of the pathway.

When the animals, A-1, A-2, and A-5, had again met our cri-

terion over four days under the conditions of Stage VI, a further change was made in the central alley. Two boards similar in size and location to those in Stage VI were employed, but now, instead of having the openings through the boards located centrally, they were located so that the animal entered the space between the boards at a point $2\frac{1}{2}$ inches from the one side wall of the central alley and left the space between the boards at a point $2\frac{1}{2}$ inches from the other side wall. That is, if the animal entered the space at the right side of the central alley, it left it at the left side of the alley and vice versa. This not only compelled the animal to use, at this part of the alley, a different path from that which it had used in Stage VI, but it also compelled the animal to turn at right angles twice in passing through the auxiliary apparatus consisting of the two boards. Furthermore, by reversing the two boards the experimenter could determine at will whether the animal was to enter the space between the boards on the right side of the central alley and leave on the left side or vice versa. In running the animals on this stage, which will hereafter be designated as Stage VII of the training, the animal was given three trials with the entrance at one side of the alley; the next four trials with the entrance on the opposite side from which it had been on the preceding three trials; and in the last three trials of the day the entrance was again in the same position as it had been in the first three trials. In each case the exit was on the side opposite the entrance. The following day's training was started with the boards in the same position as they were during the middle four trials of the preceding day's training. This method of changing the entrance from one side of the central alley to the other side after three or four trials compelled the animal to change his path slightly at this part of the central alley frequently.

In Stage VII we find that two of the animals, A-1 and A-2, required fewer trials to meet the criterion than did the third animal, A-5. These three animals completed this stage in 130, 100 and 430 trials respectively with $87\frac{1}{2}$, 90 and $87\frac{1}{2}$ per cent correct trials over the last four days. For A-1 the median delay period over the last forty trials on this stage increased by the

amount that is about typical as the animals go from stage to stage, viz., by 1 second or in this case from 3 seconds to 4 seconds. On the other hand, A-2, which completed this stage in fewer trials than did the other two, decreased the median delay period from $4\frac{1}{2}$ to 4 seconds, while A-5 which made the poorest record with respect to the number of trials required to meet the criterion made the best record on delay, the median delay for this stage being 6 seconds, an increase of 2 seconds over the median of Stage VI.

Since these three animals had given evidence, by their performance on Stages VI and VII, that their course within the central alley might be changed without making the situation so complex that the animal could no longer learn to react correctly, a still greater change of course was made by the introduction of the piece of apparatus described and diagramed as Section G under "Apparatus." This auxiliary apparatus when in position in the central alley was placed, as previously described under "Apparatus," in Section D with the entrance of Section G at the beginning of Section D and Section G extending into Section D for a distance of 14 inches. This additional apparatus again compelled the animal to enter Section D in the middle of the central alley and then directed the animal either to the right or left (as desired by the experimenter), to the corner of Section G where the animal had to change direction by bending the body sharply to one side and go for a short distance in the general direction from which it had come to the opposite corner of Section G where it was again compelled to bend the body sharply in the direction opposite to that at the last turn and then leave Section G in the middle of the central alley and slightly beyond the mid-point of Section D. The animal then went to the end of the apparatus where it made its selection of the path to the food box. The training with this setting will hereafter be designated as Stage VIII.

The same animals, A-1, A-2, and A-5, were trained with this arrangement of apparatus. As in the two preceding stages the three animals reached a point in the training where the correct responses for a given animal over forty trials averaged 85 per cent

or over, but one of the animals, A-2, did not reach the point within the training given where the correct responses on each day of the four day period were 80 per cent or above. On the third to the sixth days inclusive on Stage VIII the animal, A-2, averaged 85 per cent with a median delay period of 5 seconds, but it failed to meet our criterion for the learning since the percentages for the four days were 100, 90, 60, and 90. After that the animal did not again reach an average for any four days above 80 per cent. Thus for the period during which the animal was trained on this stage there seemed to be little or no improvement in learning. At the end of 560 trials on this stage, on the last 40 of which an average of only $57\frac{1}{2}$ per cent with a median delay of 5 seconds was made, the animal was returned to Stage V to test its performance when the central alley was unimpeded. At the end of 230 trials the animal had again met the criterion on Stage V with an average of $92\frac{1}{2}$ per cent correct choices and a median delay of 3 seconds.

The other two animals, A-1 and A-5, both met the criterion of learning on this stage, the former in 90 trials with 85 per cent correct choices and a median delay of $4\frac{1}{2}$ seconds, a delay $\frac{1}{2}$ second longer than that for the animal on Stage VII; and the latter in 210 trials with 85 per cent correct choices and a median delay of 7 seconds, an increase of 1 second over its delay on Stage VII.

Following the successful completion of Stage VIII, Rat A-1 was run on the apparatus with a different sort of arrangement. Section G was removed from Section D of the apparatus and Section H as described under "Apparatus" was inserted into Section E. When Section H was in place, it completely filled Section E so that the animal had to enter through the raised $2\frac{1}{2}$ inch circular entrance into the first compartment, pass through the $2\frac{1}{2}$ inch by $2\frac{1}{2}$ inch opening into the second compartment and out through a circular opening identical with the entrance. All three of these openings were in the middle of the central alley so that in this case again the animals were forced to follow along the mid-line of the central alley over a definite portion (22 inches) of the pathway. The training when this was in place in the ap-

paratus is designated as Stage IX when the animal has been trained successively on Stages VI, VII, and VIII following the successful completion of the first five stages and as Stage VA when the training on this follows immediately after the training on Stage V, i.e., when Stages VI, VII, and VIII have not intervened between the training on the apparatus so modified and that on the unimpeded central pathway of Stage V. Only A-1 was trained on Stage IX while A-1 again, A-2, A-4, and A-5 were all trained on Stage VA. The training on Stage VA will be reported after the results on the training on Stages IX and X have been reported.

A-1 completed Stage IX in 370 trials with 85 per cent correct responses and a median delay of 6 seconds over the last forty trials. Here again an increase of 1 second in the median length of delay over that of Stage VIII is found.

The next stage on which the animal A-1 was trained involved the same apparatus as Stage IX with the addition of sand piled before the opening of the cross partition within Section H which was in place in Section E. The animal had to dig through the sand to reach the end of the apparatus where it had to make the choice of the alley leading to food. Animal A-1 was successful in mastering this Stage. A record of 80 trials for learning with 85 per cent correct responses and a median delay of 7 seconds over the last 40 trials was made. Animal A-5 was also trained on Stage X but without having training on Stage IX; the training on Stage X in this case followed immediately after that on Stage VIII. This animal did not succeed in meeting our criterion in the 590 trials which it was given on this Stage. The record for the last 40 trials was 60 per cent correct responses with a median delay of 9 seconds while the record for the best consecutive four days was $82\frac{1}{2}$ per cent correct with a median delay of 11 seconds.

A greater complication than those described previously was then used in the training, that of including in the apparatus both Section G and Section H with the sand piled before the opening into the second compartment. Only one animal, A-1, which had successfully completed the entire sequence of stages

from I to X was trained on this next Stage, designated as Stage Xa. This animal was given 470 trials on this stage and over the last four days made 42½ per cent correct choices with a median delay of 8 seconds. The best record for four consecutive days on this stage was made within 36 days of training with 80 per cent correct choices and a median delay of 11½ seconds. Since the animal, although making 80 per cent correct choices over four consecutive days, i.e., 70, 80, 80, and 90 per cent respectively on the four days, failed to meet our criterion and at the end of the 470 trials appeared to be reacting on the basis of chance, it was returned to Stage IX for 130 trials. Failing to meet the criterion on that Stage within that number of trials, the last four days showing only 60 per cent correct responses with a median delay of 5 seconds and the best consecutive four days showing only 77½ per cent correct responses with the same median delay, training on an impeded pathway was discontinued with this animal and the animal was returned to Stage I to be retrained to the point of again meeting the criterion on each of the first five stages and then to be advanced to Stage VA.

Four animals, A-1, A-2, A-4, and A-5, were trained on Stage VA. Of these, three (A-1, A-2, A-5) had been trained on Stages VI, VII and VIII and rat A-1 had in addition been previously trained on Stage IX, the apparatus for which was exactly like that for this stage. Although A-2 and A-5 had had no training on Stage IX, yet they had had training on a stage which bore considerable resemblance to this stage, namely Stage VI. In the training on Stage VI the animal, instead of being free to follow any path through the central alley, had to pass through centrally located openings in two boards placed crosswise and four inches apart in the middle of Section D, thus necessitating the use of a path through the middle of the central alley over, at least these four inches. In Stage VA, when Section H was in position in Section E, the animal again had to make use of a path through the middle of the central alley, but one which involved passing through three openings instead of two, one which was located nearer the end of the apparatus, the first opening was 56 inches from the end in Stage VA instead of 70

inches from the end as in Stage VI, and one which controlled a longer portion of the path, 22 inches instead of 4 inches. In Table X are found the records of all the animals trained on Stages IX and VA.

It may be seen by reference to Table X that three of the four animals which were run on Stages IX and VA were successful in meeting the criterion on that stage. Two of these animals A-1 and A-2, required about the same number of trials for learning Stage VA (450 and 470 trials respectively) but the median delay periods varied from 5 seconds for animal A-1 to 7 seconds for animal A-2. Animal A-5 met the criterion on this stage in 140 trials with 85 per cent correct responses and a median

TABLE X

Showing the number of trials given, and for the last four days the per cent of correct responses and the median delay on stages IX, and VA

RAT NUMBER	STAGE NUMBER	NUMBER OF TRIALS	OVER LAST FOUR DAYS	
			Per cent correct	Median delays
				seconds
A-1	IX	370	85	6
A-1	VA	450	85	5
A-2	VA	470	85	7
A-4	VA	190	55	$3\frac{1}{2}$
A-5	VA	140	85	4

delay of 4 seconds. Animal A-4 was given only 190 trials on this stage but on the last four days of that period made only $55\frac{1}{2}$ per cent correct responses and on the best four days only $67\frac{1}{2}$ per cent correct with median delays of $3\frac{1}{2}$ seconds and 4 seconds. That animal was therefore returned to Stage I with the expectation of retraining it through the five stages before again making the attempt to train it on Stage VA. This expectation was frustrated, however, when, after the animal had relearned the first four stages in fewer trials than it had required for the original learning, it failed to meet the criterion again on Stage V even after 1260 trials had been given on that stage.

The three animals which were successful in completing Stage VA were then given training on the apparatus for that stage

with the addition of sand piled in Section H high enough to hide the opening through the middle partition. This training which will be referred to as Stage VAs, corresponds exactly to Stage X except for the training which preceded it. Animal A-1, which had learned Stage X in 80 trials with 85 per cent correct and a median delay of 7 seconds over the last four days with a record of 80 per cent correct choices with a median delay of $11\frac{1}{2}$ seconds on Stage Xa, was trained for 610 trials on this stage, but failed to meet our criterion of learning, having only $67\frac{1}{2}$ per cent correct responses with a median delay of $7\frac{1}{2}$ seconds over the last four days and only $77\frac{1}{2}$ per cent correct choices with a median delay of 7 seconds over the best four consecutive days. Animal A-2, which was given 530 trials on this stage, also failed to meet our criterion of learning, making a record of $72\frac{1}{2}$ per cent correct choices with a median delay of 8 seconds over the last four days and a record of 80 per cent correct choices with a median delay of $6\frac{1}{2}$ seconds over the best four days. The third animal, A-5, was trained for 410 trials on Stage VAs without making a record better than $77\frac{1}{2}$ per cent correct with a median delay of 9 seconds over 40 consecutive trials. It was then retrained on Stage VA which it relearned in 480 trials (90 per cent correct with a median delay of 4 seconds). When sand was then again piled before the opening in the partition of Section H, i.e., when training was resumed on Stage VAs, the animal met our criterion on the first four days with $87\frac{1}{2}$ per cent correct responses (80, 80, 100, and 90 per cent) and a median delay of $6\frac{1}{2}$ seconds. The sand was then piled higher and the training was continued with this animal until it should again meet our criterion, but this it failed to do during the 420 additional trials which were given. The best record which it made subsequent to the 40 trials on which it met the criterion was $82\frac{1}{2}$ per cent correct with a median delay of 7 seconds.

Of the animals which were trained with some impediment introduced into the central alley only those which were trained with Section H introduced before Stage V had been mastered, remained to be considered. When it became evident that these animals would not master the five stages within a period of time

that would permit training on Stages VA and VAs to be attempted, it was decided to introduce Section H into the apparatus as soon as the stage on which the animal was then being trained, had been mastered. Accordingly, for those animals Section H was placed in Section D, 28 inches farther forward than it had been placed for those animals trained on Stages IX and VA, and animals V-4, V-5, V-6 and K-7 were trained with it immediately following Stage III and animals V-9 and A-7 were trained with it immediately following Stage IV.

When the animals were trained on the apparatus including Section H immediately following Stage III the length of the path was not increased with the introduction of the section but remained the same as for Stage III and the training on this will be designated as Stage IIIA. Similarly the training on the apparatus, when Section H was included following the mastery of Stage IV, involved no increase in the length of path over that of Stage IV and it will be designated as Stage IVA.

Only two of the animals trained on Stage IIIA mastered it. Animal V-5 completed the stage in 580 trials with 85 per cent correct responses and a median delay of 2 seconds over the last four days. Animals V-4 and V-6 which failed to meet our criterion had 820 and 660 trials with $72\frac{1}{2}$ per cent and 60 per cent correct responses and a median delay of 2 seconds and 3 seconds respectively. The responses over the best four consecutive days show $77\frac{1}{2}$ per cent and $82\frac{1}{2}$ per cent correct choices with the same median delay periods as for the last four days.

Rats V-9 and A-7 were trained on Stage IVA following the completion of Stage IV but Rat K-7 was trained on Stage IVA following the mastery of Stage IIIA. In the case of animals V-9 and A-7 for which the training on Stage IVA included only 110 trials and 90 trials respectively, the training had to be terminated before they had completed the stage because of the absence of the experimenter. At the end of this training the record for the last four days for animal V-9 was 70 per cent correct choices with a median delay of 4 seconds, and for animal A-7 was $72\frac{1}{2}$ per cent correct choices with the same median delay. While on this stage Rat A-7 made no record better than that for

the last four days, Animal V-9 made a record of 75 per cent correct choices with a median delay of $4\frac{1}{2}$ seconds for the best four days. No conclusion can be drawn as to the probability that these animals would have met the criterion on this stage but we can point to the fact that these two animals had mastered the preceding stages in fewer trials than those required by any other animals.

Animal K-7 was the only one of those trained on Stage IVA that mastered it. For this 1890 trials were required and the record obtained was 90 per cent correct choices with a median delay of 3 seconds over the last four days. This animal was then advanced to Stage IVAs which corresponds to Stage IVA except that here again sand was piled so as to hide the opening through the partition in Section H. After 320 trials on this stage, in which the best record for four consecutive days was $77\frac{1}{2}$ per cent correct with a median delay of 5 seconds and the record for the last four days was 75 per cent correct with the same median delay, training was discontinued with this animal because of the absence of the experimenter from the laboratory.

From these results it will be noted that the best delay record was made on Stage Xa by animal A-1 with 80 per cent correct choices over a four day period with 70, 80, 80 and 90 per cent correct choices for the successive days. The median delay for this period was $11\frac{1}{2}$ seconds. This median was obtained from individual responses falling as follows: 2 at 10 seconds; 1 at $10\frac{1}{2}$ seconds; 12 at 11 seconds; 3 at $11\frac{1}{2}$ seconds; 9 at 12 seconds; 2 at 13 seconds; 1 at 26 seconds. The second best record also was made by an animal from Group B. This record was made on Stage X with $82\frac{1}{2}$ per cent correct responses obtained from the record of 90 per cent; 90; 70 per cent and 80 per cent for the successive days. The median delay of 11 seconds was obtained from the individual responses which were distributed as follows: 10 at 10 seconds; 2 at $10\frac{1}{2}$ seconds; 10 at 11 seconds; 7 at 12 seconds; 2 at 13 seconds; and 2 at 14 seconds. The best record for the animals in Group A is that made on Stage V by animal V-5 which showed an average of $82\frac{1}{2}$ per cent correct responses over four days, with 80, 90, 80 and 80 per cent correct on each of the four

days, and a median delay of $6\frac{1}{2}$ seconds. For Group C the best record was made by animal K-7 on Stage IVAs with $77\frac{1}{2}$ per cent correct choices over four days on which the individual days' records were 80, 90, 70 and 70 per cent correct with a median delay for the forty trials of 5 seconds.

The results for those animals trained with the various impediments placed in the central pathway are tabulated in Tables XI and XII. In Table XI is shown for each animal so trained all of the stages on which it received training together with the number of trials given on each stage, the percentage of correct responses and the median delay over the last four days, and the percentage correct and the median delay on any consecutive four days on the stage which show a record as good as or better than that on the last four days. In Table XII are shown the stages involving impediments in the central pathway together with the animals trained on each and their records as shown in Table XI.

These tables again bring out the superiority of the Auditory Group over the Visual Group and of the Visual Group over the Kinaesthetic Group both with respect to the number of animals reaching these stages and with respect to the number of stages mastered. For the convenience of the reader, Table XI presents for each rat all of the stages involving impediments on which the animal was trained. Table XII shows that four animals receiving the Visual cue, five receiving the Auditory cue and one receiving the Kinaesthetic cue were trained on the apparatus when Section H was included. The four animals receiving the Visual cue were trained with Section H in Section D of the apparatus and for three of these the path was only to the end of Section D or the same length as that for Stage III, while for the fourth it was to the end of Section E or of the same length as for Stage IV. Although in the aggregate these animals were given 2170 trials only one of them, one of those trained on the shorter path, mastered this stage. For one of the five animals with which the auditory cue was used, Section H was in Section D of the apparatus and the pathway was to the end of Section E while for the other four Section H was in Section E and the pathway extended to the end of the apparatus. With an aggre-

gate of 1340 trials for these five animals, three of them mastered the stage and all of these with the longer pathway, that extending

TABLE XI

Showing the animals, stages involving impediments on which each was trained, and results of such training

RAT NUMBER	STAGE	NUMBER OF TRIALS ON STAGE	LAST FOUR DAYS		BEST FOUR CONSECUTIVE DAYS	
			Per cent correct	Median delay	Per cent correct	Median delay
				seconds		*seconds*
V-4	IIIA	820	72½	2	77½	2
V-5	IIIA	580	85	2		
V-6	IIIA	660	60	3	82½	3
V-9	IVA	110	70	4	75	4½
A-1	VI	50	85	3		
	VII	130	87½	4		
	VIII	90	85	4½		
	IX	370	85	6		
	X	80	85	7		
	Xa	470	42½	8	80	11½
	VA	450	85	5		
	VAs	610	67½	7½	77½	7
A-2	VI	110	85	4½		
	VII	100	90	4		
	VIII	560	57½	5	85	5
	VA	470	85	7		
	VAs	530	72½	8	80	6½
A-4	VA	190	55	3½	67½	4
A-5	VI	160	87½	4		
	VII	430	87½	6		
	VIII	210	85	7		
	X	590	60	9	82½	11
	VA	140	85	4		
	VAs	870	75	7½	87½	6½*
A-7	IVA	90	72½	4		
K-7	IIIA	830	82½	2	85	2
	IVA	1,890	90	3		
	IVAs	320	75	5	77½	5

* After being trained on Stage VAs for 410 trials the animal averaged 65 per cent correct over the last 4 days. It was then returned to Stage VA for 480 trials when it met the criterion again for that stage; it was then returned to Stage VAs and averaged 87½ per cent over the first four days on this stage. The sand was then piled higher with the result that the animal did not meet the criterion.

to the end of the apparatus. Neither of the two animals which failed to meet our criterion of learning on this stage had a num-

TABLE XII

Showing the stages involving impediments, the animals trained on each, and the results

STAGE	RAT NUMBER	NUMBER OF TRIALS	LAST FOUR DAYS		BEST FOUR CONSECUTIVE DAYS	
			Per cent correct	Median delay	Per cent correct	Median delay
				seconds		*seconds*
VI	A-1	50	85	3		
	A-2	110	85	4½		
	A-5	160	87½	4		
VII	A-1	130	87½	4		
	A-2	100	90	4		
	A-5	430	87½	6		
VIII	A-1	90	85	4½		
	A-2	560	57½	5	85	5
	A-5	210	85	7		
IX	A-1	370	85	6		
X	A-1	80	85	7		
	A-5	590	60	9	82½	11
Xa	A-1	470	42½	8	80	11½
VA	A-1	450	85	5		
	A-2	470	85	7		
	A-4	190	55	3½	67½	4
	A-5	140	85	4		
VAs	A-1	610	67½	7½	77½	7
	A-2	530	72½	8	80	6½
	A-5	870	75	7½	87½	6½*
IIIA	V-4	820	72½	2	77½	2
	V-5	580	85	2		
	V-6	660	60	3	82½	3
	K-7	830	82½	2	85	2
IVA	V-9	110	70	4	75	4½
	A-7	90	72½	4		
	K-7	1,890	90	3		
IVAs	K-7	320	75	5	77½	5

* See footnote on Table XI.

ber of trials sufficient to indicate whether or not it could have learned the stage to the point demanded by our criterion. It should be pointed out that the three animals, A-1, A-2, and A-5,

which mastered Stage VA had all been trained on more stages than had animals A-4 and A-7 which failed, in the length of training given, to meet our criterion. The mere fact of having met a larger number of successively varied conditions may be a factor which makes for greater adaptability to the problem at hand. These data which have been presented here do not answer that question but they do suggest that it should be considered. This difference in the number of varied conditions on which the animals had been trained also exists between animals A-1, A-2, and A-5 and those which were trained with the visual cue. As to the age of the animals when they were put on the Stage involving Section H there is little or no difference among the three groups.

Only one animal that was trained with the kinaesthetic cue was advanced to a Stage involving an impediment in the central pathway. This animal was given training on Stages IIIA and IVA both of which it mastered, but only after a very long period of training, the number of trials for Stage IIIA being greater than that given to any other animal trained on this Stage and the number for Stage IVA being more than twice that given on Stage IIIA.

The other comparisons which might be made from this table have been given in the preceding text and need not be repeated here.

3. Training involving trials on five stages daily. In the training of the animals, whose results we have been considering above, it was found that in the great majority of cases when the animal had completed one stage of the training and was advanced to the following stage which involved the addition of a new section of the apparatus, the change in situation was sufficient to bring about a disruption of the correctness of the animal's responses on the new stage of training. Thus a greater or lesser period of training was necessary before the animal again responded correctly to the cues that were given in the new setting of the apparatus. The new stage of training not only involved a new situation, at least at the end of the central alley for any particular stage of training, but it also involved an increase in the period of

delay between the place where the stimulus was given and the place where the final selection of the side alley leading to food had to be made. The question now arose as to whether this added amount of training was necessitated as a result of the new situation at the end of the alley, or whether it was due to the increase in the length of delay period necessary to reach the point of choice, or perhaps to a combination of these two factors. In other words, if the newness of the situation were eliminated would not the animal be able to respond with about as high a percentage of correct responses at the end of Stage V as he did at the end of Stage III with other conditions as nearly constant as we could make them? Or stated still differently would the animal meet our criterion first on Stage II and then the other stages successively or would all stages be mastered at the same time?

The particular method of training which we adopted to throw some light on this problem was as follows: The discrimination was set up in the usual manner except that 15 trials per day were used instead of ten as with the animals described above. Fifteen trials per day was selected so that after the discrimination had once been set up, we might give the animal three trials each day on the unit of the apparatus used in setting up the discrimination and three trials per day on each of the units involving delay, i.e., three trials per day on the second stage; three trials on the third stage; three trials on the fourth stage and three trials on the fifth stage, thus distributing the training of each day equally over the entire five stages.

The animals selected for this part of the experiment were the animals designated as numbers 1, 7, 9, and 13. It should be borne in mind that the discrimination was set up with these animals in the same manner as it was with the group of animals designated by V (followed by the number of the animal) except that these animals received 15 trials per day instead of 10 trials. The method of training as described above was used with these animals as soon as they had met the selected criterion on the discrimination, with the results as shown in Table XIII.

Inspection of Table XIII shows that the four animals trained

in this manner benefited little from the training they received. Animal 1 received training for 104 days with three trials on each stage on each day making a total of 312 trials on each stage; Animal 13 received training for 108 days making a total of 324 trials on each stage; Animal 7 received training for 72 days with a

TABLE XIII

Table showing records of animals trained on five stages daily

RAT NUMBER	STAGE	FIRST EIGHT DAYS		LAST EIGHT DAYS		BEST EIGHT DAYS		TOTAL TRAINING		
		Per cent	Median delay	Per cent	Median delay	Per cent	Median delay	Trials	Per cent	Median delay
			seconds		*seconds*		*seconds*			*seconds*
1	I	63		67		92		312	78	
	II	58	2	58	2	88	2	312	68	2
	III	50	3	46	3	71	3	312	59	3
	IV	50	4	38	4	79	4	312	61	4
	V	58	6	46	5	63	5	312	60	5
7	I	79		75		67		216	65	
	II	54	3	54	2	79	2	216	62	2½
	III	46	3	58	3	71	3	216	58	3
	IV	58	4	63	5	58	4	216	60	4
	V	54	5	54	5½	71	7	216	56	5
9	I	67		83		79		228	69	
	II	46	2½	71	2	71	2	228	57	2
	III	58	4½	63	2½	71	3	228	58	3
	IV	58	6¼	46	3½	67	4¾	228	58	4½
	V	54	7	54	5	75	6	228	54	6½
13	I	67		96		96		324	80	
	II	63	2½	75	2	75	2	324	66	2½
	III	54	3	67	3	71	3	324	65	3½
	IV	54	4	67	4½	75	4	324	57	5
	V	46	5	71	5½	88	5	324	63	6

total of 216 trials on each stage; while Animal 9 was trained for 76 days with a total of 228 trials on each stage. It will be seen from the table that the results are tabulated in units extending over a period of eight days. This length of period was selected because the series used was of such length that the same series was repeated on every eighth day. Furthermore, this length of

period should give us a series of trials (24 over eight days) on each stage which would be somewhat comparable to the 45 trials over three days which were used in our criterion for having learned the discrimination in the case of the same animals.

Inspection of Table XIII, especially the results for the first eight days of training, will show that as soon as the situation was changed so as to give the animal only three trials each day on the discrimination stage its reactions, which previously had shown that it had learned to discriminate between the stimuli given, fell off to roughly 67 per cent correct trials in 24. This was not unexpected for the change in situation would be sufficient to produce such disruption. The results on the other stages are in all cases so low that they represent, as was to be expected again since the animal here was in a new situation, chance reactions. If the records of the last eight days of training are examined from the second main column of the Table XIII, it will be seen that in the cases of Rats 1 and 7 the table shows no improvement. The reactions on the first or discrimination stage are of about the same percentage of correctness as they were over the first eight days nor is any improvement evinced on any of the other stages. The reactions are still what we should expect from chance. In the cases of animals 9 and 13 improvement on the first stage is in evidence though it is not what one might expect after the period of training which the animals had received. It is, furthermore, very doubtful if the records on the other stages show any real improvement over the records of the first eight days. If they do show any such improvement it is more in evidence in the case of Rat 13 than in the case of Animal 9. The best records for the animals are given in the third main column of the table. These indicate some degree of improvement in the case of Animal 13 but the improvement is slight and in all probability not very reliable due to the small number of trials involved. Just why these animals did not learn to react with a higher percentage of correct responses is not shown by the original data except that all of the animals showed a decided tendency to alternate from one side to the other in reacting in that part of the apparatus involving a period of delay. Furthermore, three

trials per day on each stage did not seem to be sufficient to break up this habit of alternation. Of course, there are numerous other factors which might play a part in preventing improvement but the experimenter believes the above to be the principal reason for non-improvement under the conditions used.

When it became evident, after about two months of training with the above animals, that little or no improvement was taking place, the experimenter suspected that an element of confusion might be responsible for the establishment of the alternation habit. That is, when the two light stimuli were used, the stimulus to turn to the right was so nearly the same as the stimulus to turn to the left (the only difference being in their location) that after a period of delay the animal confused the two. It might, then, be able to respond correctly when the cue was still in evidence but after a period of delay could not do so. What would be the result if the difference between the two stimuli were made more pronounced? In order to test this, for our own satisfaction and not expecting to use the animal in the regular experiment, we selected an animal which had been kept for use but had never been started in the problem. We set up the discrimination with this animal using the following cues: when both the lights in the two stimulus boxes were turned on, it served as the cue for the animal to turn to the right; when neither of the two lights was on, it was the cue that the animal was to turn to the left. As previously reported (Cf. Section on "Setting Up Discrimination") this animal under the above conditions learned the discrimination much more rapidly than we expected and its behavior was such that we decided to continue it for at least part of the training on delay. It was given exactly the same training as the preceding four animals except for the conditions noted concerning the presentation of the cues. The results from this one animal indicate that our supposition was not entirely unfounded as is shown in Table XIV.

Examination of this table and a comparison of the results given there with those given in Table XIII for the other four animals with which the same method was used, will reveal a decided difference between the behavior of the various animals reported

in the latter table and the animal reported in the table above. It will be remembered that this animal on the last three days of setting up the discrimination had a record of 100 per cent over that period. In the above table it will be seen that this animal when put under training in the new situation maintained 83 per cent correct responses on the first stage over the first eight day period whereas the other four animals with the exception of one animal, no. 7, averaged only from 63 to 67 per cent. The difference on the remaining stages which were entirely new for the animal remained somewhat more above chance, although only slightly so, than in the case of the other four animals. The chief difference between the two tables comes out of a considera-

TABLE XIV

Showing the percentage correct, and the median delay over the first, the last and the best eight days of training and over the total training of rat 15

STAGE	FIRST EIGHT DAYS		LAST EIGHT DAYS		BEST EIGHT DAYS		TOTAL LEARNING		
	Per cent	Median delay	Per cent	Median delay	Per cent	Median delay	Trials	Per cent	Median delay
		seconds		*seconds*		*seconds*			*seconds*
I	83		100		100		120	91	
II	67	3½	92	1¾	92	1¾	120	80	2
III	58	4¼	92	2½	92	2½	120	70	3
IV	63	5	79	3½	79	3½	120	64	4
V	67	5	79	4½	79	4½	120	68	5

tion of the results over the last eight days and the best eight days of the learning in each case. Although the animals reported in Table XIII had almost three times as many trials as the animal reported in Table XIV, yet their record in no instance equalled or nearly equalled the record of this one animal. While the evidence from this one animal is not sufficient to show conclusively that the lack of improvement on the part of the four animals mentioned above was due to too great similarity of the cues used yet it greatly strengthens the supposition that such was the case.

The record for the first eight days presented in the table above shows furthermore, that during that period the animal under

consideration reacted with about the same degree of correctness on all of the four new stages of training. The record over the last eight days, on the other hand, indicates that when the same number of trials are given on the different stages the same amount of progress in the learning is not in evidence, but that the progress made on the shorter stages, i.e., those involving the shorter period of delay and the shorter path, takes place more rapidly than does that on the longer stages. This difference is shown quite plainly in the column showing the percentage of correct responses on the various stages throughout the whole training. There we find that in general, increasing the amount of delay decreases the percentage of correct responses regularly when the training has

TABLE XV

Showing the percentage correct and the median delay over the first, the last and the best eight days of training and over the total training

STAGE	FIRST EIGHT DAYS		LAST EIGHT DAYS		BEST EIGHT DAYS		TOTAL LEARNING		
	Per cent	Median delay	Per cent	Median delay	Per cent	Median delay	Trials	Per cent	Median delay
		seconds		*seconds*		*seconds*			*seconds*
I	100		100		100		144	99	
II	92	2	96	2	96	2	144	93	2
III	79	3½	92	3	96	3	144	85	3
V	67	6½	71	6	75	6	144	70	6
VS	63	10	83	9½	83	9½	144	65	9

involved the same number of trials on each length of period of delay.

After the animal had received 40 days training on each of the five stages given in the above table a change was again made in the arrangement of apparatus. Using the same number of trials per day, the animal was now trained over stages I, II, III, V, and VS. The change merely involved the elimination of Stage IV and the addition for the last three trials of the day, of Stage VS. This last stage consisted of Stage V with the addition of Section G (previously described) placed in Section D. The results from training with this setting of apparatus follow in Table XV.

It should be pointed out at this place that in Tables XIV and XV, when we speak of the "total learning" we refer only to the total learning with the five stages of the apparatus arranged as in the part which we have under consideration in the particular table involved. For example, when we say above that in the total learning the animal had 99 per cent correct responses, we mean that with this setting of the apparatus the animal had that percentage of correct responses and not over the total training that he has had on the discrimination.

Table XV shows that during the first eight days of the training with the new setting of the apparatus the animal continued to react 100 per cent correct on the first stage or, in other words, the change involved in the last part of the apparatus did not affect the reactions on the first part at all. The reactions on the second stage again give the same percentage of correct responses, namely 92 per cent, which were found for the animal's reactions on that stage during the last eight days shown in the previous Table. In the case of Stage III, however, it will be noted that whereas on the previous eight days with the other arrangement of apparatus the animal made 92 per cent correct choices, on the first eight days of the present arrangement the percentage of correct choices dropped to 79 per cent. In Stage V a similar drop is to be noted. In this case the percentage fell from 79 to 67 per cent. The drop in percentage of correct choices on these two stages is probably to be accounted for by two factors, the first of which is a result of the second. In the first place the period of delay was increased by 1 second in Stage III and by 2 seconds in the case of Stage V. This increase in the period of delay involved would seem to account for the drop in percentage of correct responses, for during the preceding eight days the animal had a median delay of $3\frac{1}{2}$ seconds on Stage IV and made 79 per cent correct choices with that length of delay. In the present arrangement the delay of that length comes in Stage III and we find the same percentage of correct responses. The increase in period of delay on Stage III over the period of delay on that stage with the preceding arrangement of apparatus is, in all probability, due to the fact that Section G, the new addition

to the apparatus, was placed in Section D when it was used as a part of Stage VS. It will be recalled that Section D was the part of the apparatus at the end of which the animal turned into the side alley when it was being trained on Stage III. Even when Section G was not in Section D, when the animal had to pass through Section D it ran slower and more cautiously as though it remembered that changed conditions existed in that part of the apparatus. This same factor accounts, in all probability, for the increased period of delay in Stage V over that found previously.

In Table XV again we note that on the last eight days of the training with this arrangement of apparatus there is a slight inversion in the percentages correct on Stages V and VS. This in all probability is to be accounted for by the fact that the last trials of the days always come on Stage VS and, due to the period of no training which followed it, it was learned more rapidly.

During the training of Rat 15 one more change of apparatus was made when the animal had reached the point of learning as shown for the last eight days in Table XV. This change consisted of dropping out the training on Stage II and training the animal on the following stages: I, III, V, VS, and VSA. Stage VSA consisted of the entire length of apparatus to the end of Stage V with the Section G in Section D of the apparatus as for Stage VS and the addition of Section H (previously described) in Section E of the apparatus. The procedure was again the same as before. The results are summarized in the following Table XVI. This animal was given only 16 days training with this arrangement of apparatus and then had to be dropped from further training due to a discontinuance of the experimental work on all of the animals concerned in this study.

Table XVI shows the results of all the training which this animal had with this particular arrangement of apparatus. The training period here was too short to show any results as far as improvement on this arrangement was concerned. It is of value, however, in that it (especially the results of the first eight days) may be compared with the last eight days of the

training with the preceding arrangement of apparatus. When this is done, we find that there has been a slight drop in the per cent of correct responses on the first stage. On Stage III which is now the second in the series in time we have 92 per cent correct responses with a median delay of $3\frac{1}{2}$ seconds. During the last eight days of training with the preceding arrangement of apparatus the animal on Stage III made 92 per cent correct responses with a median delay of 3 seconds. Thus the change of position in the series when delays involving this period of time were required did not seem to effect the correctness of the responses.

TABLE XVI

Showing the percentage correct and the median delay over the first and the last eight days of training and over the total training

STAGE	FIRST EIGHT DAYS		LAST EIGHT DAYS		TOTAL LEARNING		
	Per cent	Median delay	Per cent	Median delay	Trials	Per cent	Median delay
		seconds		*seconds*			*seconds*
I	96		96		48	96	
III	92	$3\frac{1}{2}$	96	3	48	94	$3\frac{1}{2}$
V	79	7	75	$6\frac{1}{4}$	48	77	$6\frac{1}{2}$
VS	54	11	54	8	48	54	9
VSA	67	10	58	9	48	60	10

If now we consider the results from this animal's training with respect to the period of delay involved but without regard to the Stage of training on which that length of delay was attained or the arrangement of the apparatus as the training proceeded, we find that, in general, with an increase in the length of delay there is a decrease in the percentage of correct responses. These results appear in Table XVII.

4. The influence of length of delay on the correctness of response. The report of the results obtained on the various stages on which the animals were trained in this study has indicated the records of these animals not only as to the percentage of correct responses but also as to the median length of delay on each stage. It is apparent from Tables VII, VIII, XI, XIII, XIV, XV, and XVI that the length of delay for the correct responses as shown by the

median is related to the length of the path over which the animal had to run and to the complications introduced into the path but that the proportion of the correct responses to the total number of responses for each interval of delay in seconds is not indicated. Further analysis of the data obtained in this study indicates that a relationship between the length of the delay period and the percentage of correct responses exists. Evidence for the existence of this relationship is shown in Tables XVIII, XIX and XX

TABLE XVII

Showing the total number of responses and the percentage correct for various periods of delay

LENGTH OF DELAY	TOTAL NUMBER OF RESPONSES	PER CENT CORRECT
No delay*	105	73
No delay	417	90
No delay	297	95
1 second	43	98
2 seconds	225	89
3 seconds	232	78
4 seconds	184	73
5 to 6 seconds	226	63
7 to 8 seconds	150	69
9 to 10 seconds	85	61
Over 10 seconds	80	61

* The total number and the percentage correct for the period of "no delay" are presented in three forms: first, the 105 responses which were originally required for setting up the discrimination; second, the total number of responses on Stage I including those for setting up the discrimination; and third, only those responses on Stage I when five different stages were being given each day.

in which only data obtained from the animals which were trained on ten trials per day are considered. Furthermore, in these tables are given all the responses of a given duration of delay made by the various animals of each Group regardless of the Stage on which they were made or of the period of the training in which they were made.

It will be noted from Table XVIII that for Group A, which was trained with the visual cue, the highest percentage (73.6) is for the 1 second delay period and that there is a progressive de-

crease in the percentage correct through 5 seconds. With delays above 5 seconds there is considerable fluctuation in the percentage correct which is probably due to the fact that the number of trials at each delay period is too few even for chance to operate if the animals, as we suspect that they did, were as a group reacting merely on the basis of chance. If we combine the trials from 5 seconds to 13 seconds inclusive so that we get a number of trials about equal to that at 4 seconds (2389 trials at 4 seconds and 2087 trials at 5 seconds to 13 seconds inclusive)

TABLE XVIII

Showing for the 10 animals in Group A, Set I, the total number of responses, the number correct and the percentage correct at each interval of delay in seconds

INTERVAL OF DELAY	TOTAL NUMBER	NUMBER CORRECT	PER CENT CORRECT
seconds			
1	1,665	1,226	73.6
2	6,838	4,560	66.6
3	6,581	4,136	62.8
4	2,389	1,356	56.7
5	1,034	557	53.8
6	448	260	58.0
7	205	116	56.5
8	147	75	51.0
9	87	49	56.3
10	77	47	61.0
11	31	20	65.5
12	35	20	57.0
13	23	14	61.0
Over 13	130	65	50.0

we find that the percentage correct is slightly below that for 4 seconds or is 55.4 and that for the trials on which there was a delay of more than 13 seconds the percentage decreases to just chance or 50 per cent.

With Group B the increase in the length of delay shows a regular decrease in the percentage of correct responses to 13 seconds at which delay period an inversion appears. At the 13 seconds delay is found the smallest number of trials, only 65 in number, so these were combined with the trials on which the delay was more than 13 seconds. This gave for 278 trials 61.1

per cent correct choices or a result in accord with the rest of Table X1X. If the longer delay periods are analyzed further, we find that if we combine the trials for 11 seconds and 12 seconds, for 13 seconds to 18 seconds inclusive and for all trials on which the delay was longer than 18 seconds, the number of trials and the percentage correct are 562 trials with 63.7 per cent correct, 210 trials with 63.3 per cent correct and 63 trials with 53.6 per cent correct respectively. Thus it may be seen that for this group of animals it is not until a delay period of more than 18

TABLE XIX

Showing for the 7 animals in Group B, the total number of responses, the number correct and the percentage correct at each interval of delay in seconds

INTERVAL OF DELAY	TOTAL NUMBER	NUMBER CORRECT	PER CENT CORRECT
seconds			
1	1,027	812	79.1
2	2,946	2,196	74.5
3	3,720	2,684	72.1
4	3,436	2,419	70.4
5	1,560	1,081	69.2
6	1,136	769	67.6
7	1,184	798	67.3
8	822	542	65.9
9	557	370	66.4
10	504	333	66.0
11	367	237	64.5
12	195	121	62.0
13	63	50	79.5
Over 13	215	120	55.8

seconds is reached that we find them reacting on what seems to be a purely chance basis.

From Table XX in which the results on the length of delay and the percentage of correct responses are reported for Group C, we see that the percentage of correct responses over each of the first four delay periods are about the same as for Group A except that the percentage correct for 1 second is lower, 67.8 per cent instead of 73.6 per cent. In the case of these animals as with those of groups A and B combinations of the trials for those periods of delay which involve a small number of trials show the

delay period beyond which the responses seem to be merely chance. For this group a combination of 6 seconds to 8 seconds inclusive gives 248 trials with 52.4 per cent correct responses and a combination of all delays 9 seconds or longer gives 124 trials with 50 per cent correct responses for the successive seconds.

The abrupt drop in the number of responses for the successive seconds of delay which appear for Group A at 8 seconds and for Group C at 6 seconds is not apparent for Group B. The explanation for the greater proportion of responses at the longer

TABLE XX

Showing for the 8 animals in Group C, the total number of responses, the number correct and the percentage correct at each interval of delay in seconds

INTERVAL OF DELAY	TOTAL NUMBER	NUMBER CORRECT	PER CENT CORRECT
seconds			
1	3,258	2,211	67.8
2	7,770	5,089	65.4
3	5,092	3,240	63.6
4	1,234	706	57.2
5	364	192	52.7
6	133	64	48.1
7	80	41	51.2
8	35	25	71.5
9	23	12	52.1
10	25	14	56.0
11	11	4	36.4
12	11	8	72.5
13	13	4	30.8
Over 13	41	20	48.7

delay periods for Group B than for either Group A or Group C lies in the number of times in which the animals in the various groups were trained in the more advanced stages. It cannot be due to the aggregate number of trials that were given to the three groups of animals since for Group C the aggregate was 17,750 while for Groups A and B the aggregates of the trials were 19,690 and 18,090 respectively.

It was to be expected that the percentages correct at each delay period would be higher for Group B than for either of the other groups since the animals of Group B showed better learn-

TABLE XXI

Showing for each animal the total number of responses and the percentage correct at each interval of delay in seconds

RAT	1 SECOND		2 SECONDS		3 SECONDS		4 SECONDS		5 SECONDS		6 SECONDS		7 SECONDS		8 SECONDS		9 SECONDS		10 SECONDS		11 SECONDS		12 SECONDS		13 SECONDS		OVER	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
V-1	41	68	420	68	534	58	192	51	58	57	37	65	19	68	16	44	7	71	3	67			1	100	3	67	9	67
V-2	334	73	1,152	63	1,345	64	554	55	257	50	120	45	55	51	46	52	39	54	22	36	13	38	12	67	7	57	64	52
V-3	57	77	502	54	80	64	11	100	9	33	7	57	3	0	1	0	1	0	2	100			1	100	1	100	5	60
V-4	445	72	1,766	70	676	77	226	53	125	53	55	58	21	62	18	44	7	57	21	74	4	50	4	50	4	25	28	57
V-5	429	76	1,678	62	1,050	68	642	64	343	61	142	67	47	66	29	69	11	64	9	89	2	100	8	50	1	100	9	56
V-6	191	65	212	72	686	66	170	57	125	46	44	52	32	59	23	44	14	50	13	62	12	92	8	50	6	67	14	36
V-7	17	82	424	70	972	63	222	55	49	49	15	60	11	45	5	60	2	50	2	50			1	0				
V-8	43	84	439	64	971	54	245	51	37	41	13	54	2	100	7	29	2	100	1	100								
V-9	47	92	115	72	117	69	94	62	20	80	13	69	5	60	1	100	3	67	4	50							1	0
V-10	61	87	130	70	147	56	33	58	11	67	2	0	3	67	1	0	1	0							1	100		
A-1	76	90	510	78	1,220	73	668	71	295	70	398	68	461	69	206	63	135	72	173	66	147	64	57	66			25	72
A-2	78	90	585	81	524	76	630	71	587	71	338	69	228	60	176	63	113	53	63	64	27	59	25	44	10	50	36	44
A-3	149	76	361	68	323	66	122	55	53	60	52	62	43	56	18	56	13	69	9	33	7	43	3	33	6	83	11	55
A-4	492	74	978	68	1,154	69	1,080	64	185	67	55	52	27	59	11	64	3	33	4	100	2	0	2	50	1	0	6	17
A-5	120	83	333	79	363	83	871	79	411	71	286	70	422	71	408	69	301	67	254	67	183	68	107	65	46	63	136	49
A-6	43	91	75	87	31	55	5	60	3	67	1	100			1	100	1	0										
A-7	69	86	104	71	105	83	60	72	26	50	6	67	3	33	2	50	1	0	1	0	1	100	1	100			1	0
K-1	410	66	1,484	67	1,362	60	470	57	117	50	25	40	28	43	7	86	1	0	6	50	3	0	2	100	1	0	4	50
K-2																												
K-3	653	72	1,777	64	414	65	108	55	50	54	22	55	13	33	4	100	4	50	3	67	3	67	1	100	5	20	13	77
K-4	952	68	1,245	60	213	54	53	58	39	44	16	56	9	67	3	100	5	40	5	60	2	50	4	50	2	50	12	50
K-5																												
K-6	519	75	1,619	68	1,160	62	288	57	75	59	37	51	10	60	9	56	5	80	4	75	1	100	3	67	2	50	8	25
K-7	433	63	1,186	71	1,699	69	273	60	76	55	26	46	17	65	11	55	7	43	5	40	2	0	1	100	2	50	2	50
K-8	291	56	459	60	244	64	42	48	7	43	7	29	3	67	1	100	1	100	2	50					1	0	2	0

ing on all of the stages and mastered more stages than did the animals of the other groups. As a consequence of meeting our criterion for so many stages and, frequently, of doing so with a relatively small number of trials the percentage must of necessity be higher than for those groups in which the animals either failed to meet our criterion or met it only after long continued training. These animals of Group B were probably reacting to the cue and not reacting on the basis of chance, at least a part of the time, with delays up to 18 seconds.

Not only from the foregoing tables (XVIII, XIX, XX) in which the animals are considered in groups, but also from Table XXI in which the number of trials and the percentage correct for each delay period in seconds is reported for each animal, is evidence found for the relationship between length of delay and the correctness of response. As long as a sufficient number of trials is represented, practically every animal shows the general tendency toward a decrease in the percentage correct with an increase in the length of delay. Additional evidence for the superiority of Group B over the other two groups appears in this table. In general, beyond the 1 second delay the animals in Group B show a higher percentage correct than do the animals of the other Groups.

C. Summary of experimental results

The following statements will serve as a summary of the experimental findings reported in the preceding pages of this section:

1. All of the animals used in the problem except two that were trained on the kinaesthetic cues learned the discrimination.

2. Only one of the animals that learned the discrimination failed to complete to the point of meeting our criterion, at least, one of the stages involving delay.

3. A summary of the number of animals completing each stage shows that our criterion was met by 23 of the 25 animals on Stage I; by 22 of the 23 on Stage II; by 14 of the 22 on Stage III; by 7 of the 12 on Stage IV; by 4 of the 7 on Stage V; by all of the 3 on Stage VI; by all of the 3 on Stage VII; by 2 of the 3 on Stage

VIII, by the one on Stage IX; by 1 of the 2 on Stage X; by none of the 1 on Stage Xa; by none of the 4 on Stage IIIA; by 1 of the 2 on Stage IVA; by none of the 1 on Stage IVAs; by 3 of the 4 on Stage VA and by none of the 3 on Stage VAs.

4. The group trained with the auditory cues showed superiority over the group trained with the visual and the kinaesthetic cues both as to the number and the difficulty of the stages completed and as to the maximal length of delay attained. The superiority held not only for the groups as a whole but for the best and the poorest animals of the groups.

5. The maximal delay period as found in the experiment was a median delay of $11\frac{1}{2}$ seconds for 80 per cent correct choices and 11 seconds for $82\frac{1}{2}$ per cent correct choices over four consecutive days for 2 animals trained with the auditory cue. The maximal delays for the animals trained with the visual cue was $6\frac{1}{2}$ seconds at $82\frac{1}{2}$ per cent correct responses over four days and for the animals trained with the kinaesthetic cues was 5 seconds with only $77\frac{1}{2}$ per cent correct choices. The inclusion of the animal trained with visual cues arranged as the presence or absence of light in the stimulus boxes shows for animals trained on vision a maximal delay of $9\frac{1}{2}$ seconds with 83 per cent correct responses over an eight day period involving 24 trials.

6. The introduction into the central pathway of auxiliary apparatus designed to impede the animal's progress sufficiently to lengthen the delay period and to disrupt differential overt bodily attitudes, if such were present, did not make the problem too difficult for mastery.

VI. DISCUSSION

In the section on Introduction it was stated that in any study of the delayed response two principal questions arise. These were stated as follows:

1. How long after the determining stimulus has been removed can the animal still make the correct response to that stimulus, and
2. What is the mechanism by means of which such a correct response is made possible when the determining stimulus is no longer present?

In this section we shall consider the relation of the experimental results obtained in the present study with those of previous studies and their bearing on the two main questions mentioned above.

A. The period of time over which the animal can delay

1. The maximal delay found in the present study. According to our predetermined criterion the animal gave evidence of ability to react correctly on a given stage of the problem when that animal had maintained over a four day period or for forty consecutive trials a consistently high percentage of correct responses, specifically 85 per cent correct over the four day period, with no day showing less than 80 per cent correct. The period of delay was then to be determined by the median length of the individual correct responses. The median was chosen because with the method used it was impossible to obtain delays of exactly the same length over all of the trials. Invariably there was some variation in the length of response, usually, however, over a range of only two or three seconds. In many cases if the mean length of delay instead of the median length of delay had been used, the length of delay reported would have been greater. Such would necessarily have been the case since for each stage there was a minimal delay period below which no response could be made so that any extreme case must fall above the median and would thus weight the mean unduly.

When we use the median delay over the best forty trials we find that the maximal delays were made by two animals in Group B, namely, animals A-1 and A-5. While these animals did not meet our criterion yet they so nearly attained it that considering that the stages on which they made these median lengths of delay were the most difficult, these delays are taken as our maximal delays. In the case of animal A-1 the record was made on Stage Xa with 80 per cent correct choices over the four day period with a median delay of $11\frac{1}{2}$ seconds. For the other animal, A-5, the record was made on Stage X with $82\frac{1}{2}$ per cent correct choices over the four day period with a median delay of 11 seconds. Among the animals of Group A or those trained on

the visual cue, the best record was made by Animal V-5, which made on Stage V an average of 82½ per cent correct responses over the best four day period with a median delay of 6½ seconds. If we include with these animals the one animal that was trained on 15 trials per day with light vs. darkness stimuli, the best record for those animals trained with visual cues, is that of Animal 15 for which the highest delay over the eight day period was 9½ seconds with 83 per cent correct responses on Stage V. The best record made by any animal in Group C was made by K-7 on Stage IVAs on which it showed 77½ per cent correct responses over four days with a median delay of 5 seconds.

It may be seen from the maximal delay obtained with animals from the various groups that the longest delay was found in the case of the animals of the Auditory Group. One's first impression might lead him to conclude that auditory stimulation is more effective than is visual stimulation for obtaining the delayed response in this situation. This conclusion can not be drawn from the above evidence without qualification, however. In Section IV under General Method it was suggested that the cues employed with the Auditory Group and the Visual Group were not sufficiently comparable to make possible any definite conclusions as to the most effective sense to be employed in the study of the delayed response. This possibility receives additional support from the evidence obtained from the record of Animal 15 which was trained with visual stimuli made more nearly comparable to the auditory cues by training the animal to respond to the presence or absence of a light stimulus as the Auditory Group had been trained to react to the presence or absence of the sound stimulus. With this animal it was found that a longer delay could be attained by the animal in a considerably briefer period of training than was the case with the other animals trained on vision. This was equally true whether the animal was trained with ten or fifteen trials per day and when the animal was kept continuously on one stage until it was mastered or when the animal was trained on the five stages simultaneously. On the other hand, that this animal made a record in length of delay attained more nearly similar to that of the Auditory Group

than did those animals which were trained to react to the position of the light may be a result of the different criterion used to determine mastery of the period of delay and not of the difference in the effectiveness of the cues. Furthermore, from a consideration of the evidence from the setting-up of the discrimination it may be seen that the difference between the Auditory and the Visual Groups trained on ten trials per day is slight while the latter animal, no. 15 seemed to have an advantage even for setting up the discrimination. This might indicate that our criterion was lower in the case of this one animal than in the others or it might indicate that the animal was a particularly precocious one. From the evidence at hand then, we are unable to say definitely which of the two types of stimulation is the more effective for the study of the delayed response. We can say, however, on the basis of the experimental results, that comparing the two situations as a whole, the auditory was superior to the visual situation. When we compare the results obtained with the group of animals trained to discriminate on the basis of the presence or absence of the inclined plane with the group trained on the auditory stimuli, there can be no question but that the auditory stimuli were the more effective for the study of the delayed response.

2. Comparison of maximal delay periods obtained in the present study with those obtained by other experimenters. As was pointed out in Section II of this study two previous workers have utilized the albino rat as subject in the delayed reaction experiment. The first of these, Hunter (6) found a maximal delay with this animal of 10 seconds, in the case of one rat when the animal was offered a possibility of the choice of one of three compartments. With the remainder of his animals he found that in the three compartment situations they were unable to delay longer than for 1 second except in the case of three animals which delayed for periods of 3 seconds, 3 seconds, and 4 seconds, respectively. When, however, he took three of the animals that could delay only 1 second in the three compartment situation and tested them on a two compartment situation he found that the animal could delay for periods up to 5 seconds. From his results it would

appear that one might expect the delays possible in the two compartment situation to be about 5 times as long as in the three compartment situation. Yarborough's (21) results from a study of the cat in a situation as nearly as possible similar to that of Hunter's found about the same relationship to exist between the period of delay obtained with two compartments and those obtained with three compartments.

The second experimenter who utilized the albino rat as subject in the delayed response situation was Ulrich (18). This experimenter using apparatus similar to Hunter's except that it was larger and had several changes made in arrangement, found that he could obtain delays of considerably greater length. As was pointed out in the section on previous work the number of trials used was so few and the percentage of correct responses obtained was so low in most cases that the present experimenter questions their reliability as measures of the animal's ability to delay. Furthermore, again as previously pointed out, it is somewhat questionable whether the proper controls were exercised in this experiment to insure that the animal was not reacting on the basis of some other cue which was present in the situation. It should be added, however, that this experimenter was not primarily interested in studying the delayed reaction in this experiment, but rather the integration of movement in learning in the albino rat.

If we now compare the maximal delays obtained by the above experimenters with the animal in the three compartment situation with the maximal delays obtained in this experiment we find that considering only the length of delay obtained our animals did not do appreciably better than did Hunter's one animal with the 10 second delay. We do find, however, that the majority of animals trained on vision in this experiment did delay longer than did the majority of Hunter's animals. If, however, we estimate what the various animals used by Hunter would have done had they been tested out on a two box arrangement, from the results which he obtained when he used only two compartments in the case of three of the animals it is quite evident that Hunter's animals would have had a better record than did the

animals in this study. This shorter delay in this study is in all probability due to several factors which we shall consider at this point.

To the present experimenter it appears that one of the chief reasons for failing to find, in this study, delays as long as those estimated for Hunter's animals in a two choice situation is that in this investigation the criterion was considerably more difficult to attain than was the criterion in Hunter's experiment. In this experiment the animal was retained on a given stage until it had given evidence of having ability to react correctly after the period of delay which was under consideration. The evidence of that ability was furnished in the present experiment by the animal's performance over a four day period in which it met the arbitrary criterion which we had set up; namely, that over the series of forty trials it made 85 per cent correct choices with not less than 80 per cent correct choices on any single day's series of ten trials. In Hunter's experiment, on the other hand, no such rigid standard was set up. In Hunter's experiment there was considerable variability in the standards as to the percentage of correct responses required of an animal before it should be advanced to a longer delay period. In addition to the percentage of correct responses he took into consideration behavior indications such as "hesitancies and waverings." While such criteria may be satisfactory to determine the maximal amount of delay of which the animal is capable; yet, when we come to the question as to the mechanism by means of which the animal is able to react correctly after delay, the more objective the evidence and the less dependent it is upon the behavior observations by the experimenter, the more satisfactory and reliable it is. Our criterion of 85 per cent correct over 40 trials is a percentage which gives us a difference from chance which is statistically reliable even though we had not further increased its reliability by requiring that this be obtained with not less than 80 per cent correct for each series of 10 trials composing the forty.

If the present criterion had been lower the animals would have advanced more rapidly from stage to stage and consequently would have covered a larger number of stages provided they had

not reached their limit of delay sooner. This is apparent from the fact that for most of the animals which failed to meet our criterion on the last stage on which they were trained, there were found four consecutive days over which the percentage correct was 75 or above. In several cases this percentage was 85 which satisfied the first part of our criterion but which did not advance the animal to the next stage since the last part was not satisfied.

Another factor in the present study which tended to decrease the length of time over which the animal could delay is found in the fact that when the animal completed the fifth stage of the training impediments were introduced into the central pathway which in addition to increasing the length of time required for the animal to run to the end of the apparatus complicated the problem so as to make the correct response more difficult. In some cases the longer time required for running through the pathway was due to an actual lengthening of path, in others it was due merely to a retardation of the animal's speed as it passed through constricted openings while in still others it was due to the necessity for making an additional series of movements such as digging before the animal could reach the point at which the choice of path to food could be made. These impediments, especially that in which the animal had to engage in an activity other than running, would tend to shorten the time over which the animal could delay successfully.

Another possible explanation of the shorter delay periods lies in the difference between this study and Hunter's study in method of presentation of the stimuli. In Hunter's study the light to which the animal was to react, was turned on for a period of 5 seconds during which the animal could "get set" for the particular response. In the present study the animal could not react to the stimulus until the release box was opened and then only for the length of time required for running from the release box to a point between the light boxes, A′ and B′, or that distance over which it passed in Stage I. If we judge this time (which could not be measured since the experimenter had to attend to the presentation if the stimulus and to the measuring of the time

of delay), from the time required to run through Stage II, this time could have been little if any, more than 1 second and many times was probably less. That such an estimate is legitimate would seem reasonable since the distance from the release box to the position where the cue was no longer present was only $13\frac{1}{2}$ inches while the distance over which the delay was measured for Stage II was 22 inches and since there was no appreciable difference in the rate of running the two parts because the animal was set to run before the opening of the release box.

In addition to these possibilities there is, of course, the possibility that, were these factors inoperative, the situation of this experiment was intrinsically of such a nature that no longer delay periods could have been attained. One would expect, however, that this was the least likely of the possibilities.

The two experimenters who have worked on the delayed reaction problem, since the work reported in this monograph was undertaken, obtained longer delays than either Hunter or the present writer. Maier's (26) set-up and method were both so radically different from that used by either Hunter or the present writer that comparison of results is almost impossible. Honzik's (27) method and apparatus are more nearly comparable to those used by Hunter as well as those used in the present study. His results differ from those obtained in this study not only in showing longer maximal delay periods but also in that with the increase in the delay periods no decrease in the percentage of correct responses appeared within the limits studied, viz., 7 seconds, 15 seconds, 30 seconds and 45 seconds.

In most reports of the experimental results on the delayed reaction, an attempt is made to relate the particular experimental findings reported with the results found on other species on the same or even in radically different situations. To the writer that procedure does not appear legitimate. Sufficient evidence has been collected with the various species to show that the period of delay is definitely a function of the method used and the particular situation involved. The only comparison that we could make would be with those studies that used the indirect method; namely those of Hunter (6), Yarborough (21), and

Walton (19). Even such comparisons are reliable only in so far as the situations in these studies are comparable. As far as the maximal length of delay is concerned, little actual difference appears between Hunter's rats, the rats in this experiment and Yarborough's cats.

B. Evidence as to the basis for reaction after delay

Two possibilities must be considered in regard to the basis on which the correct response may be made after a period of delay. These are (1) the maintenance of overt bodily attitudes and (2) the mediation of some non-observable intra-organic cues. Previous work with the rat has shown that the former of these is used by that animal. Hunter has presented conclusive evidence that in his study such was the case and that the bodily attitude used was gross bodily orientation. In the "Introduction" we pointed out the possibility that the particular situation in which Hunter investigated the delayed response might have been particularly conducive to the establishment of that mode of response. There too, it was indicated that the question arises as to whether in other situations the rat must use the same method of bridging the delay or whether it may show a different mode of behavior in a different situation where orientation would be more difficult.

We shall now consider the various possibilities of, and the evidence in regard to reaction by the animals in the present problem on the basis of observable, differential bodily attitudes during delay.

The first possibility to be considered is that of gross bodily orientation. If the animal used this mode of bridging the delay between the time of the disappearance of the stimulus and the making of the choice of the correct path, it would have to incline its body in the direction of the entrance to the path which would lead to reward. This would mean that in the situation used in the present experiment, the animal would either follow a diagonal path from the exit of Section B, the narrow space between the light boxes which protruded into the central alley at that point, to the exit from the central alley to the side alley or,

with its body inclined somewhat diagonally, it would run directly forward and then at the end of the central alley make the choice in accord with that inclination. Except during the first few trials after an animal had been advanced to a new stage such behavior was rarely found, and on the more advanced stages, after the second or third stages, it was never found. Animals were observed to incline the body to one side or the other, but such behavior appeared so infrequently and the behavior at the end of the alley was so inconsistent that no prediction could be made as to which side the animal would choose when it reached the end of the alley. This seems to rule out this possibility of gross bodily orientation in the present situation.

Another possibility of solution is that the animal, when it reached the end of Section B of the apparatus would make its choice of path at that point and as a consequence turn directly to the right or left as the case might be and then follow the side wall of the central alley on that side to its end and then turn into the side alley on the side of the central alley upon which it was running. This form of behavior would indicate of course, that the animal was not making a delayed response, in the sense ordinarily used, but that the choice was made as for the discrimination and the side wall was being used as a secondary cue. This behavior did appear early in the learning when an animal had been moved to a new stage. Then it sometimes happened that in the first few trials on the new stage, the animal followed a central path to the point at which it had been accustomed to making the choice of the side alley and then turned to the side according to the stimulus given. Finding the exit closed at that point the animal then continued along the wall until the exit was reached. This behavior continued only for a few trials, however, until the animal became more or less habituated to the new length of pathway. After this a definite pathway within the central alley was again selected and followed more or less regularly by the animal.

There were some animals which, when they entered the broad central alley, invariably turned to the side and followed the side wall more or less closely to the end of the alley where the

choice of path was made. For these animals, a path along one side of the central pathway became habitual and was followed irrespective of the side for which the cue was given and irrespective of the choice which the animal was to make. No evidence was found with these animals, when they were reacting so as to meet the criterion, that, at the end of the alley, they turned more frequently to the side favored in the central alley than they did to the other side. The behavior of the animals which followed such a path was indicative that the side wall was not used as a differential cue in making the choice of the path to food.

Another form of orientation that suggests itself as a possible means of bridging the delay is that of pointing the head toward the side on which the correct response must be made. Only negative evidence in regard to this appears from observation of the animal's behavior. No instance was observed in which this appeared.

There are other possibilities such as the possibility that although the animal did not orient by turning either its body or its head, yet it might have followed the side wall by means of vision. This possibility seems *a priori* rather improbable and evidence from the behavior of the animal seems to support this. It was observed at times that when the length of path in the central pathway was increased, the animal ran to the end of the previous stage and then turned toward the side. Had the animal been following the side wall by means of vision it is probable that the opening into the side alley on the side followed by vision would have been the stimulus to turn, since this was not present the animal should under those conditions continue directly forward until that was observed, but this was not the case. In a few cases the animals showed indications of having discovered that the end board had been moved by coming to an abrupt stop at the end of the old pathway and then, without making the usual turn, proceeding cautiously and hesitantly into the unfamiliar part of the apparatus until the end wall was reached. There it hesitated and finally made a choice of side alley by turning toward the opening on one side or the other.

Further indication that the above possibilities are improbable is furnished by the records of the animals on those stages involving the various impediments. This is especially noteworthy in the case of those stages on which digging through sand or passing through the S-shaped box was required. In those two situations reaction on the basis of any of the possibilities mentioned thus far seems extremely doubtful. In digging through sand, the animal showed considerable muscular activity and frequently changes of position. In passing through the S-shaped box the animal was required by the sharp turns to twist its body first in one direction and then in the other.

These experimental controls were, furthermore, of such a nature that they render highly improbable the maintenance of muscular tensions on one side or the other of the animal's body. Had such a basis been necessary for bridging the delay the stages in which these controls were used probably could not have been mastered since this muscular tension would have been lost by the animals as they twisted their bodies first one way and then the other, or as they engaged in the vigorous activity of digging. There is the further possibility that muscular tensions were present as the animal left the stimulus compartment but were lost as the animal engaged in the activity required to pass through these impediments, and then reinstated as the animal again ran forward. This seems improbable, since, if they had been strong enough for reinstatement, they would probably have been manifested in some form of overt behavior such as has been considered. Since we find no evidence for bodily attitudes which might provide a basis for the animal's ability to react correctly following a period of delay, we must conclude that the basis for the reaction is in some intra-organic cue. For the animals which failed to complete more than the simpler stages and which were able to bridge only $1\frac{1}{2}$ second or 2 second delays no indication was obtained as to their method of bridging the delay other than behavior observations which, though they are insufficient to provide any satisfactory evidence, indicate that at least, gross bodily orientation was not present. For those animals, however, that completed the stages involving impediments, es-

pecially those that include digging through sand and passing through the S-shaped box, the evidence seems to indicate that they reacted on cues other than those furnished by possible orientation.

The next question which naturally arises is concerned with the nature of the intra-organic cues on the basis of which the animal reacts after the period of delay. The present study provides no new experimental evidence of the nature of such cues nor does the present experimenter have any new contribution to offer in this respect. Various possibilities of such reaction have been suggested.

Among these possibilities we would mention that suggested by Watson (20) namely, that what may be happening is that when the stimulus is presented a definite set of arcs is released which functions serially and thus serves as the basis for responding correctly at the end of the central pathway. Our problem is of such a nature that the general situation would be favorable for reaction on such a basis. However, it is not probable that, in the part of the training involving the S-shaped box or digging through sand, such a simple basis was present for here the behavior required was so varied that a disruption of these serially connected arcs would likely have taken place. In that case they would have had to be reinstated either immediately after the animal had passed through that part of the apparatus or at least at the time when the choice was made. In such a case the question arises as to the mode of this reinstatement. Watson has said that there is no known mechanism to account for such reinstatement. Hunter, on the other hand, has pointed out that in addition to the functioning of these serially connected arcs there may be present intra-organic processes which can be rearoused without the presence of the external stimulus. Furthermore, he has pointed out (Psychological Bulletin, 1915, 12, 189–190) that there are kinaesthetic factors, having great importance for animal behavior, which can be aroused in such a manner and from that concludes that the intra-organic factors concerned in reaction after delay, where orientation has not been present, are probably kinaesthetic in nature. As previously

stated the present study furnishes no new evidence on this problem.

VII. SUMMARY AND CONCLUSIONS

On the basis of the experimental findings reported in this study, the following conclusions may be drawn:

1. The delayed reaction was investigated in a situation in which the animal was kept in motion during the period of delay instead of being confined in a small compartment as in previous investigations.

2. The maximal delay period for the albino rat obtained in this study was $11\frac{1}{2}$ seconds, the median time of delay on the correct runs when the animal made 80 per cent correct responses over 40 consecutive trials.

3. The maximal delay period here obtained was shorter than that estimated for Hunter's rats had his best animals been tested with two choices instead of three. Possible explanations of this fact may be made on the basis of the higher standard of performance required by our criterion of learning; the great complexity of our problem in the higher stages, and the differences in the method of presenting the stimuli.

4. Reaction in the situation present in this study was found, at least in some cases, not to be on the basis of overt bodily attitudes. Evidence for this was found in the animal's general behavior and in his ability to react correctly after such attitudes, had they existed, must have been disrupted.

5. The experimental evidence presented indicates that some of the animals reacted on the basis of some intra-organic cues, the nature of which cannot be determined from the data collected in this study.

6. Visual, auditory and kinaesthetic stimuli were all effective in producing correct response after delay.

7. No definite conclusion can be drawn as to the relative effectiveness of auditory and visual stimulation for producing correct response after delay.

8. Both visual and auditory stimulation as used were more effective for obtaining correct reaction after delay than was the

particular type of kinaesthetic stimulation which was made use of in this study. The superiority of the two former types of stimulation was shown by (a) the best stages reached in the experiment; (b) the number of trials necessary to attain the highest stage; (c) the delay period actually attained.

9. An inverse relationship was found between the percentage of correct responses and the length of delay as is shown by a comparison of the percentages of correct responses for the various delay periods irrespective of the length or condition of the pathway upon which they were made.

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